December 1961

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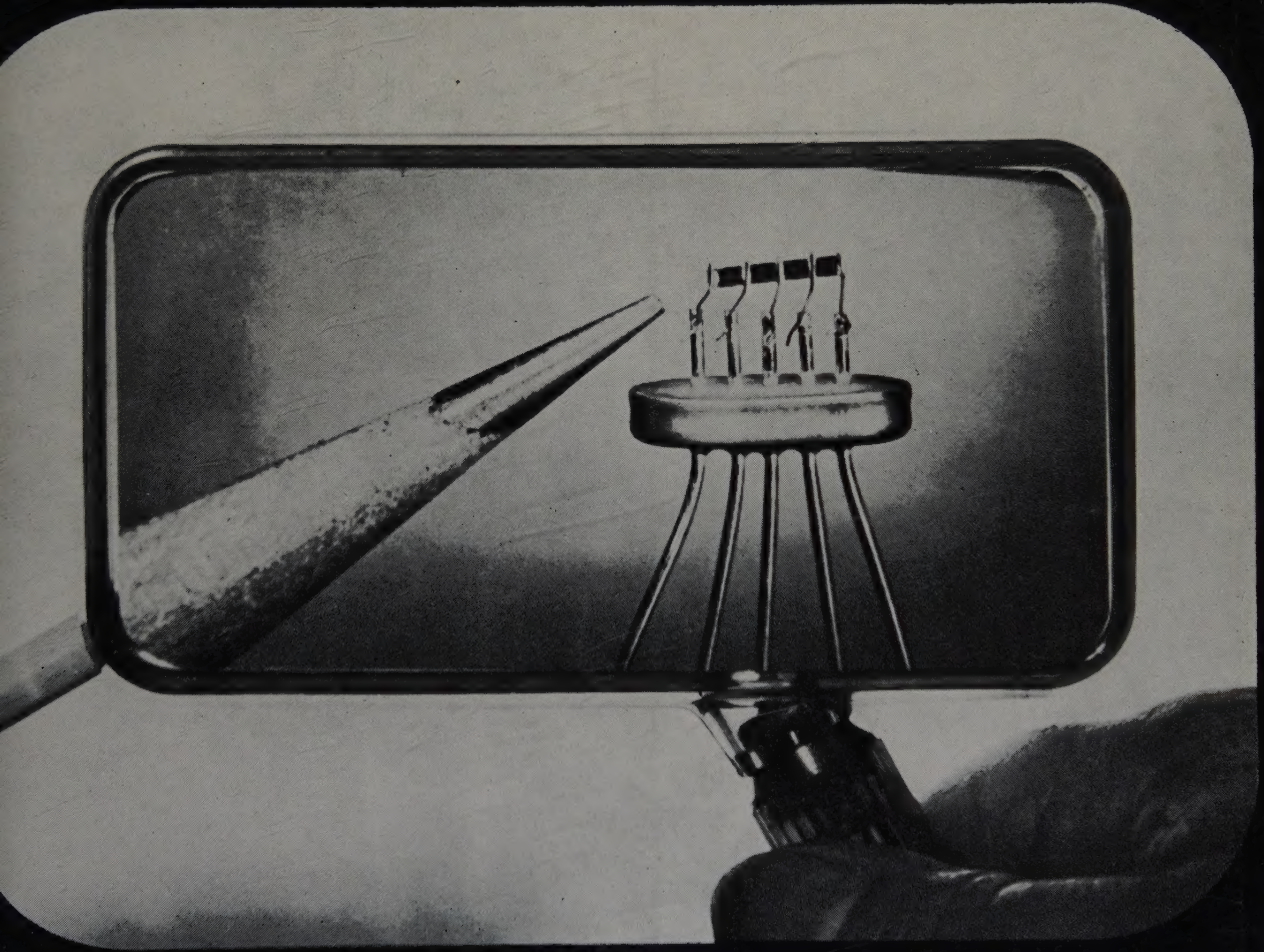

The Chargistor

Power Semiconductor Load Current Ratings

Design Considerations for Schmitt Trigger

Measuring the Resistivity of Silicon

Pulling Single Crystals

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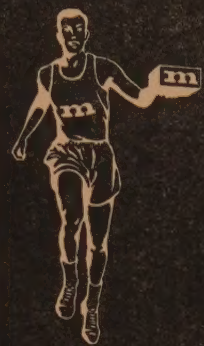

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Information On

THE DIODE SOURCE BOOK

See Pages 54, 55

August 1961

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

December 1961 Vol. 4 No. 12

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Front Cover

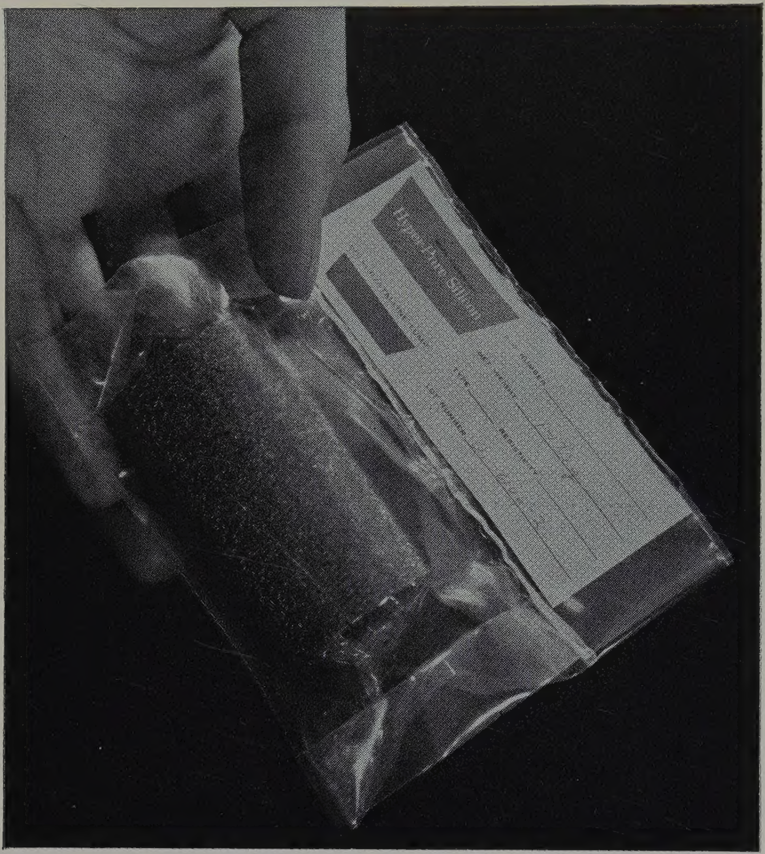
The Chargistor, developed by International Business Machines Corporation is an experimental semiconductor device not much larger than the point of a lead pencil. The solid-state component has certain characteristics previously available only in vacuum tubes, such as high voltage operating capability and multi-control elements. Device shown has five surface junction contacts. Three of these act like grids of a vacuum tube and control electric current flow through a bar of intrinsic germanium which serves as conducting channel. High voltage performance is possible because no single junction sustains entire voltage applied across the conducting channel. Operation of the device at 200 volts with greater than one megacycle frequency response, has been demonstrated in experiments at IBM's Advanced Systems Development Division Laboratory.

SILICON NEWS from Dow Corning

(Part 4)

The Untouchables

Specify Crucible Charges of Deposited Hyper-Pure Silicon



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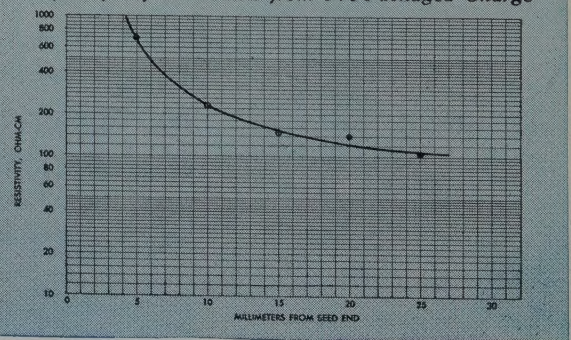
Profile of Crystal Grown from Pre-Packaged Charge



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Semiconductor Products

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Current Books

Thermoelectricity edited by Paul H. Egli. John Wiley & Sons, Inc., New York, N.Y. $10.00. This book covers the fundamental concepts of thermoelectricity, physics, and high-temperature problems.

Mechanical Properties of Intermetallic Compounds edited by J. H. Westbrook. John Wiley & Sons, Inc., New York, N.Y. $9.50. Based on a Symposium held in Philadelphia in May 1959, sponsored by the Electrothermics and Metallurgy Division of The Electrochemical Society, Inc.

Mathematical Handbook for Scientists and Engineers by G. A. Korn and T. M. Korn. McGraw-Hill Book Company, Inc., New York, N.Y. $20.00. Among the many subjects covered are algebra, analytic geometry, calculus, vector analysis, integrals, Fourier analysis, Laplace transformations, differential equations, Boolean algebra, tensors, probability, and random processes.

Boron Synthesis, Structure, and Properties edited by J. A. Kohn, W. F. Nye, and G. Gaule. Plenum Press, New York, N.Y. $8.50. Proceedings of the Conference on Boron.

Theory and Application of Ferrites by Ronald F. Soohoo. Prentice-Hall, Inc., Englewood Cliffs, N.J., $12.00. A combined treatment of ferrites—at microwave frequencies and below microwave frequencies.

Properties of Elemental and Compound Semiconductors edited by Harry C. Gates. Interscience Publishers, New York, N.Y. $8.50. Proceedings of a Technical Conference sponsored by the Semiconductors Committee of the Institute of Metals Division, The Metallurgical Society.

Analogue Computers by I. I. Eterman. Pergamon Press, New York, N.Y. $8.50. In this book, a Russian translation, particular attention is paid to the mathematical sections of analogue computer theory and to the various methods of applying the machines to secure the particular mathematical conditions for arriving at a solution.

Infrared Radiation by Henry L. Hackforth. McGraw-Hill Book Company, Inc., New York, N.Y. $10.00. Here is a reference and guide to infrared radiation—what it is, what it does, and how it is used.

Electronic Circuit Analysis, Vol. 1, Passive Networks by Phillip Cutler. McGraw-Hill Book Company, Inc., New York, N.Y. $8.00. The purpose of this book is to build a solid foundation in the basic concepts and techniques essential to mastering problems of analysis, design, and maintenance of electronic equipment.

Industrial Electronics Made Easy by Tom Jaski. Gernsback Library, Inc., New York, N.Y. $3.95 in soft cover; $5.95 in hard cover. An analysis of industrial generators. Techniques for transducers, servos, computers, counters, and display devices.

Nuclear Pulse Spectrometry by Robert L. Chase. McGraw-Hill Book Company, New York, N.Y. $8.50. Here are thorough discussions of the electronic techniques and physical principles related to the problems of cataloging the electrical signals from nuclear radiation detectors.

Basic Electrical Measurements by M. B. Stout. Second edition. Prentice-Hall, Inc., Englewood Cliffs, N.J. $13.00. A thorough updating of a comprehensive, flexible, problem-oriented presentation of measuring principles and practices.

Advances in Spectroscopy, Vol. 1 edited by H. W. Thompson. Interscience Publishers, Inc., New York, N.Y. $12.50. The first in a series of annual volumes which will present, interpret, and evaluate significant recent accomplishments in spectroscopy and indicate the most promising lines of advance.

Electronics Math Simplified by Alan Andrews. Howard W. Sams & Co., Inc., Indianapolis, Ind. $4.95. For the engineer student or technician who requires a knowledge of mathematics as it relates to electronics.

Industrial Electronics Measurement and Control by Edward Bukstein. Howard W. Sams & Co., Inc., Indianapolis, Ind. $3.95. Complete coverage of the equipment and techniques used in modern-day production and processing systems.

International Transistor Substitution Guidebook by Keats A. Pullen, Jr. John F. Rider Publisher, Inc., New York, N.Y. $1.50. Over 4500 direct substitutions of American, Japanese, British, Dutch, French, Italian and German manufacture.

Rare Earth Research edited by Eugene V. Kleber. The Macmillan Company, New York, N.Y. $9.75. This is the first book-length treatment of research on this group of sixteen metals so vital to the fields of electronics, nuclear science, ceramics and metallurgy.

Industrial Control Electronics by Matthew Mandl. Prentice-Hall, Inc., Englewood Cliffs, N.J. $10.65. A practical approach to the study of industrial electronics and control for anyone with a rudimentary knowledge of the basic principles of electronics.

Refractory Metals and Alloys edited by M. Semchyshen and J. J. Harwood. Interscience Publishers, New York, N.Y. $22.00. Metallurgical Society Conference, Vol. 11.

The Dynamic Behavior of Thermoelectric Devices by Paul E. Gray. John Wiley & Sons, Inc., New York, N.Y. $3.50. This is the first published report that investigates the small-signal behavior of thermoelectric devices.

New Literature

Lindberg Engineering Company has issued Bulletin 1521 detailing the features and equipment of their Radio Frequency Heating Unit Model L1-15D-1. The unit is a vacuum-tube type converter designed to convert power line energy to high-frequency electrical energy suitable for induction heating.

Circle 170 on Reader Service Card

A complete line of automatic equipment for high production coating of electrical and electronic components is described and illustrated in a new brochure available from Conforming Matrix Corporation. Included are a remote masking spray coater, a powdered resin coating machine, automatic tray loading machine and magazine loader.

Circle 171 on Reader Service Card

Monsanto Chemical Company is now making available a revised manual for the evaluation of III-V intermetallic semiconductors. Two new sections have been added to the original manual. The new publication now describes the procedure for the preparation of single crystal gallium arsenide for evaluation; the X-ray method for orienting gallium arsenide crystals; procedure for evaluation of Hall coefficient and resistivity of gallium arsenide, and the procedure for measurement of dislocation density in gallium arsenide.

Circle 172 on Reader Service Card

An information bulletin telling how to end seal electronic components for environmental protection is available from Epoxy Products Division, Joseph Waldman and Sons. A step-by-step description of end sealing is given including pellet composition, selection of a sleeve material and important design considerations. Processing variables which must be controlled for a good end seal are explained and analyzed.

Circle 173 on Reader Service Card

A chart of "do's and don'ts" on precision welding is offered as a production aid by Raytheon Company's Commercial Apparatus & Systems Division. Printed on heavy card stock for posting at work stations, the two-color chart describes and illustrates 14 major tips for better welding, especially where precise, highly reliable welds are required, such as in dense packaging of semiconductors and other small electronic components.

Circle 174 on Reader Service Card

Applied Pneumatics, Inc., announces a new 4-page catalog on Heatless Dryers, Purifying Systems, and Miniature Compressors. The literature describes dryers, hydrogenous adsorbers, and central systems for producing clean, pure, extremely low dewpoint air and other gases for Military, Industrial, and Laboratory uses. Catalog 61 illustrates six new units designed to meet all applicable Military specifications and producing capacities to 30 SCFM.

Circle 175 on Reader Service Card

(Continued on page 13)

Looking for a compact 1 to 10 watt Germanium Power Transistor with this kind of top level performance?

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- *Gain*—h_{FE} 30 min @ 0.2 amp; h_{FE} 20 min @ 1.0 amp
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(14)

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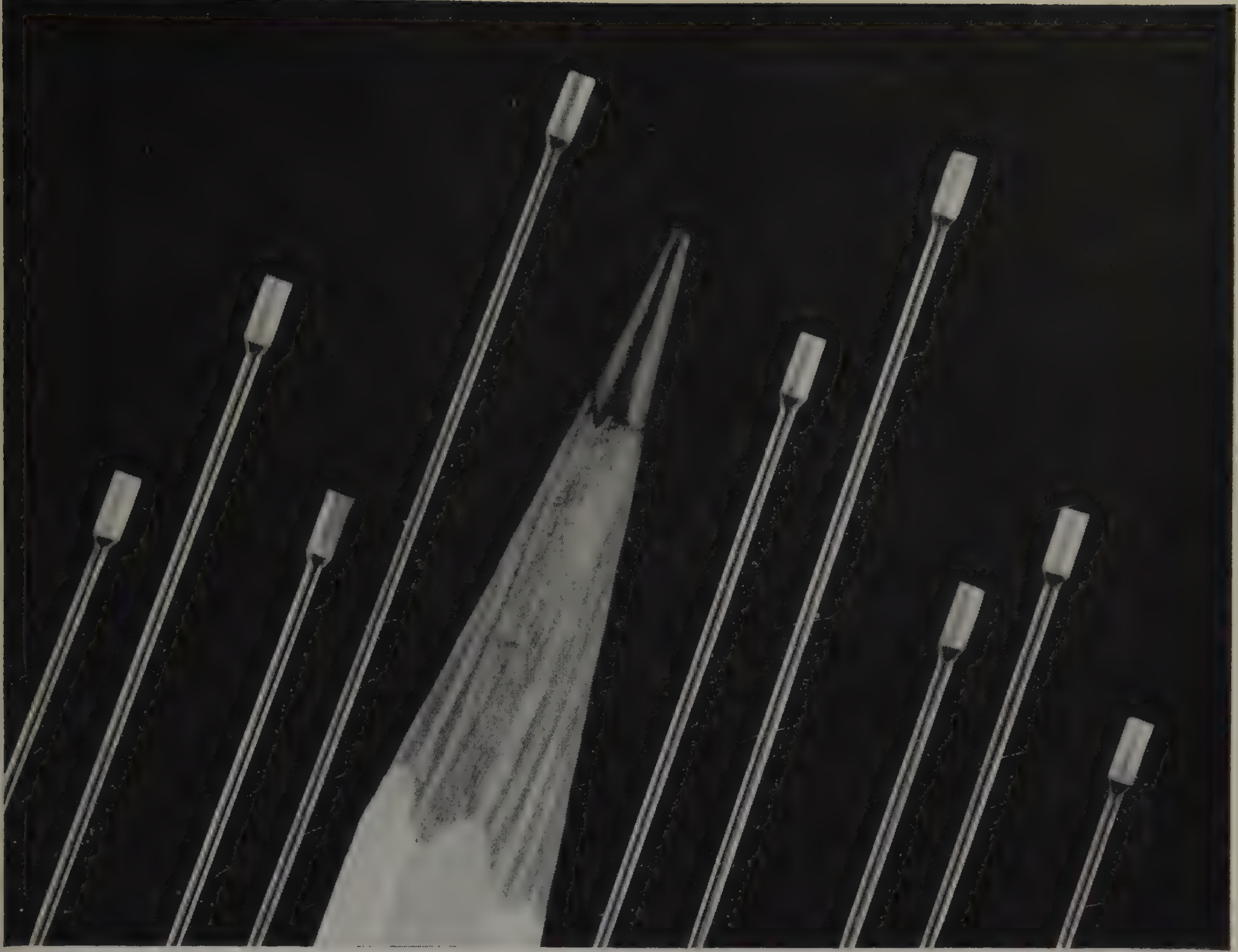

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steps up reliability... cuts shrinkage

Now for the first time, Sylvania makes available mass production quantities of diode Dumet lead wires by utilizing its fully automated production facilities. A typical lead wire features a slug made from specially developed Sylvania diode Dumet .040″ in diameter x .100″ long. A pigtail wire is concentrically welded to it and measures .020″ in diameter and up to 1½″ long.

Result? Semiconductor device manufacturers are assured of improved component reliability, significantly less shrinkage, and small packages. You get better heat dissipation from the semiconductor device, and may now rate your devices at a higher wattage. (Naturally, the size of the slug and the wire can be tailored to your specifications within limits.)

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For full details on the new Sylvania diode lead—plus welds, cans, headers, connectors, and alloy cuts and leads, just write Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania.

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New Literature
(from page 7)

Bulletin 1550 illustrates and describes both bench and floor models within Blue M's new series of Stabil-Glow Box Type Furnaces. It provides specifications on equipment used for heat treating and annealing of ferrous and non-ferrous metals, assaying, research, ignition of precipitates, optical glass heat treating, fusions, ash determinations, hardening of high speed steels, sintering of powdered metals, copper brazing, aging, forging and laboratory procedures involving ceramics.

Circle 176 on Reader Service Card

Heller Industries' new Lead Master machine which trims and forms leads of axial components without special tooling set up, is described in a new bulletin. The data covers how production variables are provided for by simple dial adjustment and also lists the wide range of component sizes handled. Production rates are as high as 11,000 per hour.

Circle 177 on Reader Service Card

Literature, describing the new Wil-Gard Tru-Touch Disposable Vinyl Industrial Glove, is available from the Wilson Rubber Co., Industrial Division.

Circle 178 on Reader Service Card

New 48 page IERC Test Report 172A gives junction and case temperatures, power dissipation for power transistors in a variety of natural and forced air environments. The general compilation of data in the Test Report provides one of the most complete coverages of transistor heat dissipator design and effectiveness. Coordinated with the text are graphs, charts and drawings, as well as full-page photographs of the environmental test laboratory set-ups to fully present the subject.

Circle 179 on Reader Service Card

A new catalogue describing a complete line of high-reliability Germanium Gold Bonded Diodes for the government and industrial markets has been announced by National Transistor Manufacturing Incorporated. The four-page, attractively illustrated booklet, Bulletin A-101, gives the characteristics and physical specifications for approximately 150 subminiature glass diodes, including computer types, high reverse resistance types, and high forward conductance types.

Circle 181 on Reader Service Card

Hughes Aircraft Company, Semiconductor Division, has published a 110 page bulletin on single crystal silicon available from stock. Specifications of properties such as type, growth method, resistivity, lifetime, and weight are given for each crystal.

Circle 182 on Reader Service Card

A highly useful chart providing thermal, physical, chemical and electrical characteristics of HumiSeal protective coatings for electronic applications is being made available by Columbia Technical Corporation. This informative chart, No. C-503, is a complete revision and was prepared so that all characteristics can be seen at a glance on one side of the sheet. The ten HumiSeal types contained in it are broken down by the A.I.E.E. thermal classification as well as 47 other specific characteristics for each type.

Circle 183 on Reader Service Card

Industry

CONFERENCE CALENDAR

The Following January 1961 Meetings Are Scheduled:

Jan 9-11 8th National Symposium on Reliability and Quality Control, Statler Hilton Hotel, Wash., D. C. Sponsored by PGRQC, AIEE, ASQC, EIA. For Information: E. F. Jahr, IBM Corp., Dept. 351, Owego, N. Y.

Jan 24-27 10th Annual Physics Show, New York City, Sponsored by American Institute of Physics.

Jan 29-Feb 2 Winter General Meeting AIEE Electrical Engineering Exposition, New York City Coliseum. Sponsored by AIEE. For Information: N. S. Hibshman, Exec. Secy., AIEE, 33 W. 39th St., N. Y. 18, N. Y.

GENERAL NEWS

P. E. Haggerty, President-Elect of the 90,000 member Institute of Radio Engineers, and Warren H. Chase, President of the 70,000 American Institute of Electrical Engineers, have conferred on first steps to consolidate their organizations into one international engineering society. The Boards of Directors of AIEE and IRE have appointed a committee to study the question and to make a report by February 15, 1962. The plan will be submitted to the membership of both organizations. If approved, target date for "consummation" is January 1, 1963. Mr. Haggerty is President of Texas Instruments, Inc., Dallas, and Mr. Chase is Vice President of the Ohio Bell Telephone Company.

Dr. Guy Suits, General Electric vice president and director of research, has been chosen to receive the 1962 Industrial Research Institute Medal. The award was announced at the fall meeting of the Institute by Dr. Howard S. Turner, Institute president, who is vice president for research and development of the Jones and Laughlin Steel Corporation. The Industrial Research Institute, representing 175 U.S. companies, cites Dr. Suits' "skill and leadership in promoting the growth of an industrial research laboratory enjoying world-wide recognition; one which has provided its scientists with the freedom, opportunity and facilities to pursue fundamental studies in many areas of science and yet is finely integrated with the company's technological requirements for growth and prosperity." In the citation of the Institute Dr. Suits is also honored "for successfully interpreting research results to company managment and the general public and for varied technological advisory services to the government of his country."

The silicon transistor was approved for space communications at the Fall General Meeting of the American Institute of Electrical Engineers. Because of its reliability, "the silicon transistor is far superior" to one made of germanium, W. B. Allen, manager of the Product Engineering Department, Research and Development Division, Hughes Aircraft Company, Culver City, Calif., told a space communications symposium. His conclusion was contained in a paper, "The Application of Solid State Devices to Space Telecommunications."

News . . .

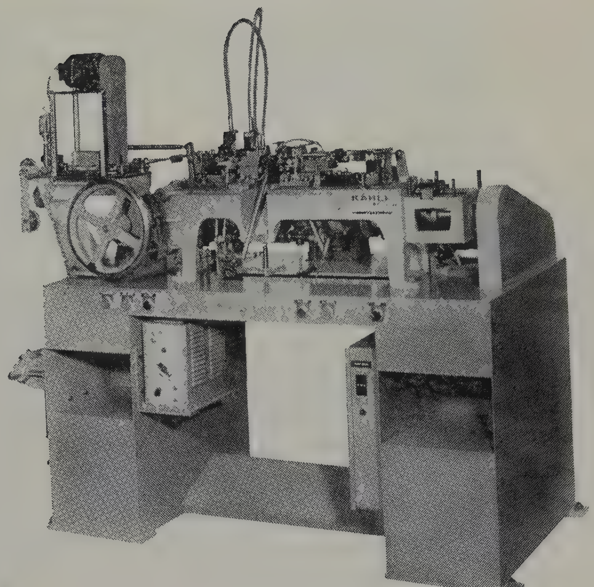
Research spending in the United States will amount to almost \$16 billion in 1962, predicted Battelle Institute economist George W. James at the forecasting session of the annual meeting of the National Association of Business Economists in Chicago. Dr. James estimated that the government would spend about \$10 billion for research next year, reflecting stepped-up space and defense programs; industry about \$5.5 billion, up \$600 million from the 1961 estimate; and universities and foundations about \$350 million. By comparison, research spending in the United States totaled \$14 billion in 1960 and only \$3 billion in 1950. "If research were considered an industry," he said, "its total 'sales' would rank it about midway among the 20 major manufacturing industries in the United States. And approximately 350,000 professional people are employed in research today, a number equal to just under one-half of the total production employees of the automotive industries."

Industrial white rooms, which have received a great degree of success largely as a result of the semiconductor industry, have now reached their limit of effectiveness, according to Stuart L. Parsons, general manager of the Equipment Manufacturing Operations of Philco Corporation. Mr. Parsons explained that white rooms have provided adequate environmental control during the first decade of semiconductor manufacture. But, the more recent high volume production rates and the increasing advances in solid state science have greatly compounded atmosphere control problems. He said that adequate and economical environmental control for today's expanded semiconductor industry can only be obtained by very close control of contaminants in very limited isolated areas, within a larger "clean room" area.

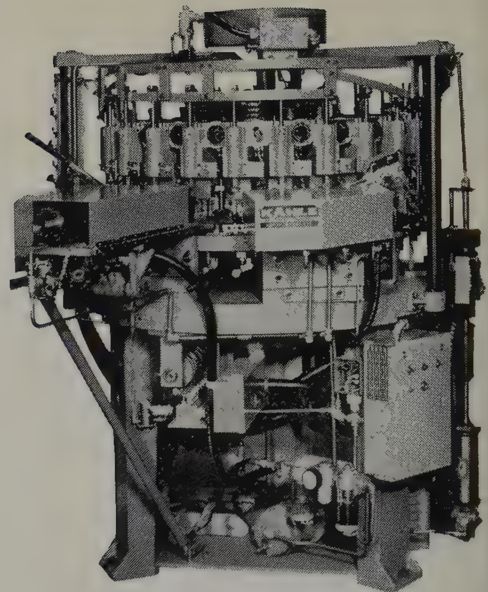
The Birtcher Corporation/Industrial Division announces a new laboratory for research and development to advance the state of the art of electronic heat transfer devices and thermal problems relating to electronic packaging. In making the announcement, vice president Charles F. Booher, in charge of the firm's industrial division, said the new lab is completely equipped to simulate problems of heat transfer necessary to develop and design more sophisticated devices than are now available to electronic engineers. Equipment includes environmental chambers to simulate varying internal and external ambients and flow patterns, and calibrating equipment to enable direct measurement of transistor and other semiconductor thermal problems, in which the transistor's own junction will act as a thermocouple to measure heat transfer.

A new five year fuel cell research and development program similar to that carried on in this country between Leesona Moos Laboratories, a division of Leesona Corporation, and United Aircraft Corporation has gotten under way in Great Britain, Robert Leeson, president of Leesona Corporation, announced. British fuel cell development has been carried on by the National Research Development Corporation (NRDC), a government-sponsored research group with which Leesona Corporation has cross-licensing agreements. The program will be conducted by a new corporation to be known as Energy Conversion, Ltd., in which NRDC will be associated with three British industrial companies.

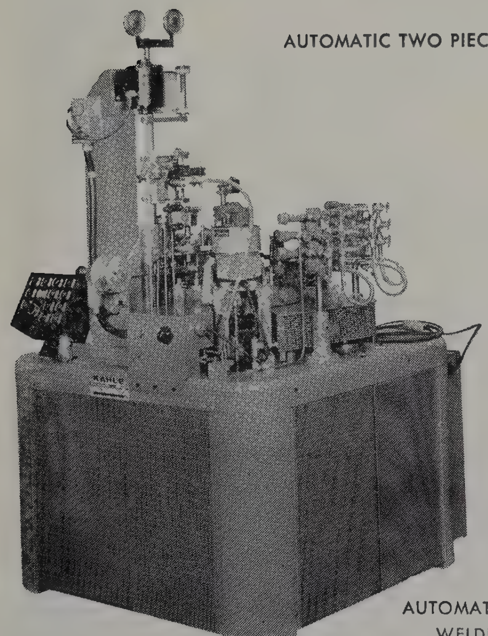
(Continued on page 52)



AUTOMATIC TWO PIECE LEAD WELDER 3648



AUTOMATIC FINAL SEAL 3383



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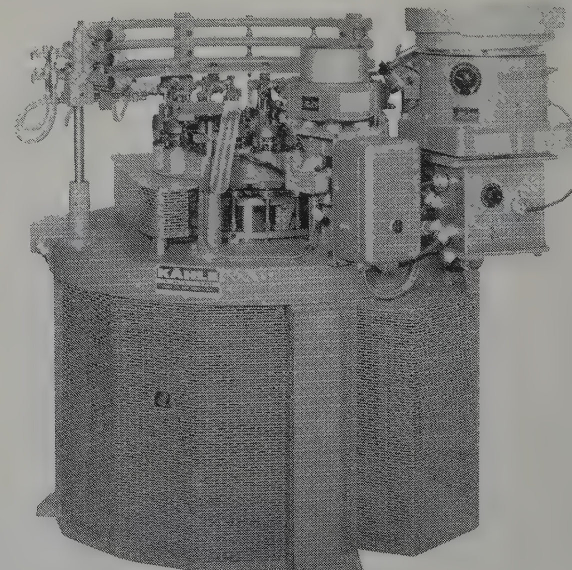

AUTOMATIC BODY CASE (MOLY OR DUMET SLUG LEAD OR GLASS BEAD) 3624

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Editorial . . .

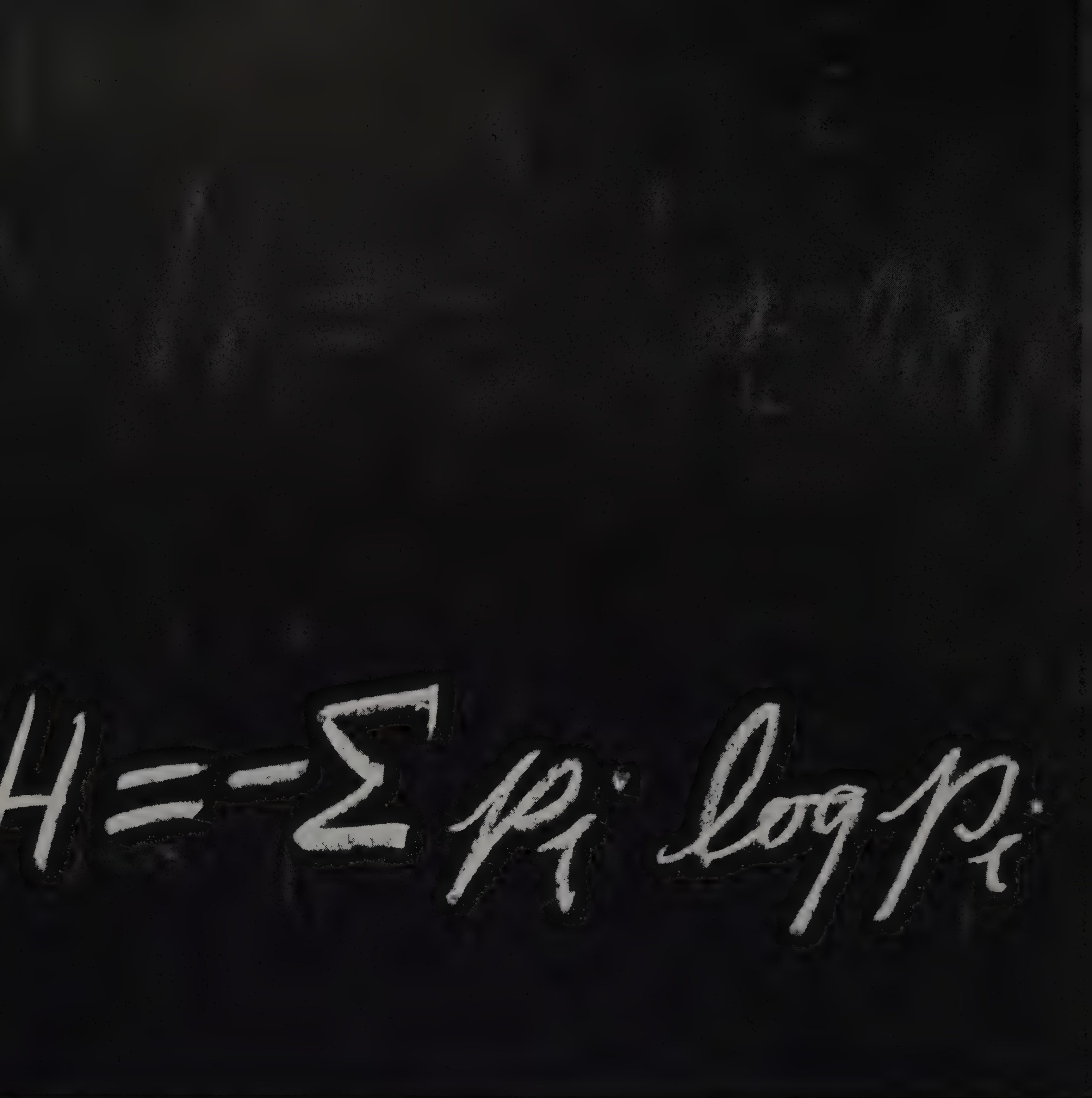
Advances in Transistor Fabrication

Study of the injection efficiency, transport factor, collector reverse current, collector breakdown voltage, collector-to-base capacitance, and collector saturation resistance, shows that conflicting requirements must be satisfied sometimes in order to obtain ideal transistor characteristics. High injection efficiency requires that the emitter conductivity be much larger than that of the base, large transport factor requires that the base width be very small, or that diffused structures be used such that built-in accelerating fields are created in the base. On the other hand, low collector conductivity corresponds to low collector capacitance, large breakdown voltage, large saturation resistance, and large reverse collector current.

For several years the choice of collector conductance has been a matter of compromise; the suggestion that the collector region be made with two separate layers, with the layer closer to the base having lower conductivity, was advanced, but the state of the art did not permit a satisfactory practical realization until recently. The breakthrough was obtained with the fabrication of an epitaxial layer on a substrate of silicon or germanium, obtained by chemical deposition.

The wafer of substrate material of large conductivity is placed in a reducing atmosphere of hydrogen and a suitable halide, with the additional presence of the required dopant impurity. By reduction, an epitaxial layer of controllable thickness and conductivity is deposited on the surface of the substrate. For example, in the case of silicon, this wafer is brought to a temperature of 1200° C in the presence of hydrogen and silicon tetrachloride.

The fabrication of epitaxial transistors has represented a considerable step forward in the state of the art, bringing closer the realization of the universal transistor; usable for linear amplification and for switching, for low and for large signals, and for low and high frequencies. In fact these transistors are found to possess low saturation resistance, high collector breakdown voltage, low collector capacitance, very linear current amplification factor, very high collector efficiency, very low dissipation in the "on" switching state, and very low pulse storage effect.



A basic formula from Information Theory . . . provides a measure of the amount of information in a particular type of message, such as TV . . . helps determine the frequency bandwidth, for example, required to transmit the messages. Information Theory, pioneered at Bell Laboratories, guides the search for better communications systems.

DISCOVERY AT BELL TELEPHONE LABORATORIES

New knowledge comes in many forms. Sometimes it comes in a mathematical formula. Usually it comes after much thought and experiment and the fruitful interaction of different minds and abilities. Most often, too, a particular discovery is small. But many small discoveries have a way of leading to big advances at Bell Laboratories—advances like the transistor . . . or, more recently, the gaseous optical maser, forerunner of communications at optical frequencies. Opportunities for discovery are enhanced by the abilities of the scientists and engineers and the range of the facilities at Bell Laboratories, *world center of communications research and development.*

AMERICAN TELEPHONE & TELEGRAPH CO. BELL SYSTEM AND ASSOCIATED COMPANIES

An Up-To-Date Look at Power Semiconductor Load Current Ratings

F. W. GUTZWILLER*

As the refinement of semiconductor fabrication technology yields an increasingly consistent product, it becomes possible to rate a semiconductor for the exact requirements of a specific application with confidence. This permits maximum utilization of the semiconductor along with an improvement in predictable performance and reliability. This article presents the major considerations in rating and applying present and future generations of such power semiconductors from a load current standpoint.

SEMICONDUCTOR LOAD RATINGS have come a long way since the first current ratings were crudely developed with a hunch, a straight edge, and crossed fingers. In the ensuing years, rating of semiconductors has become a science which lends itself to exact approaches and to the use of computer techniques. Specification sheets for semiconductor devices have developed from a few lines of "typical" data to impressive multi-page arrays of printed and graphical data defining what a specific device is and is not guaranteed to do. Such prolific information tends to cloud an important fact: ratings are simply yellow warning lights to exercise caution. Nothing catastrophic should magically occur the instant one exceeds a specific rating by a slight degree. The maximum ratings of a reputable manufacturer warn of encroaching reliability problems on some small but significant portion of a sample of semiconductors if those ratings are substantially exceeded. The objective manufacturer with a reputation to uphold has to draw a line defining what he guarantees his semiconductor will do. The rating is that line, arbitrary as that line may sometimes appear to be to the casual user.

A well-developed set of ratings that is based on a sound philosophy has a real value in addition to its "protect-the-user" and "protect-the-manufacturer" roles. Ratings are an all-important design tool for the component user. Even though his conditions may be altogether different from the life test conditions to which the manufacturer subjects a specific type of semiconductor, the user can apply that semiconductor with confidence, using the rating curves as his means for correlating and predicting satisfactory performance. The effective rating system is a substitute for objective life tests run under every conceivable combination of application conditions: ambient temperature, voltage, current, frequency, etc. Time and economics prohibit testing at each of the infinite variety of test conditions that are possible. Instead, ample life tests on significant samples of a given semiconductor type under a single set of well-defined conditions, *plus* a valid rating system proved by limited tests for correlation to other conditions, is both logical and effective.

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Temperature

The semiconductor junction is both the functional heart of the device and also its hottest spot when in operation. The temperature of the junction directly affects essentially all of the main ratings in one way or another. Maximum allowable junction temperature ratings are limited by long term stability requirements on device characteristics, by thermal runaway criteria, and by temperature dependence of the characteristics themselves. For instance, a 400 volt silicon controlled rectifier may have a maximum junction temperaure rating of 150°C, because temperatures above this value reduce the forward blocking ability of the device below 400 volts. On the other hand, conventional silicon rectifiers are usually limited to 200°C because of thermal stability considerations and the effects of surface contamination at high PRV's. Also, the joints in some devices may melt at temperatures above 200°C.

At the other end of the temperature scale is a minimum temperature specification, too often taken quite lightly by user and component manufacturer as well. Silicon metal is fragile, and the mechanical stresses on it when used in semiconductor assemblies increase greatly as temperature is reduced below the melting points of the assembly. These stresses and their effects on device characteristics generally become most severe on high power devices because of the large area of their junctions. The enclosure for the semiconductor may also limit low temperature operation since

the joints between metals and insulators tend to crack and lose their hermetic seal properties as the mercury descends, or as wide temperature swings suddenly occur. Good low temperature capability can be significant even in the application that never reaches these low temperatures, for it can be rationally hypothesized that a semiconductor that is good at —65°C is just that much more reliable at 0°C compared to a semiconductor that can't withstand —65°C.

Temperature Excursion

So much for temperature itself. Some associated factors that tend to be overlooked in evaluating power semiconductors are their ability to withstand high rates of change in temperature, and repeated temperature changes. A high rate of change in temperature is typical of applications where a large load is suddenly applied to a device at low temperature. This causes a temperature shock which can set up destructive stresses due to the high differential temperature within the device itself. Good design and effective process control eliminates this as a serious problem. Military specifications adequately cover tests and conditions for checking for temperature shock.

The second phenomenon mentioned above, repeated temperature changes, can lead to thermal fatigue. This is analogous to a time bomb whose ticks are counted off by the number of times the device is subjected to a wide temperature change, whether incurred by ambient temperature changes or changes in load current. Damage to a semiconductor from thermal fatigue usually centers in the soft solders used to attach the junction pellet or sandwich to the heatsink or stud. As the temperature of the device is raised and lowered, the stresses on this solder joint are alternately reduced, and then increased again due to the unequal temperature coefficients of the material on each side of the joint. These stresses are a function of the junction area, and are generally more severe for higher power devices. After a limited number of these temperature excursions, the solder joint of a poorly design semiconductor will start to deteriorate as minute cracks begin to appear in the solder. The thermal conductivity of the joint worsens, and eventually the junction overheats and is destroyed. The thermal fatigue characteristics of a typical silicon rectifier type subject to this phenomenon are shown in Fig. 1. Note that the number of thermal cycles to failure is an inverse function of the temperature excursion. Unless the junction temperature of this kind of silicon device is kept to an impractically low excursion of 50 to 60°C by drastic current derating, it will eventually fail due to the phenomenon of thermal fatigue.

In the past year, power semiconductors have been introduced to the market that overcome thermal fatigue limitations in the normal life span of the device. For the most part, these new designs utilize hard high-temperature solders for all joints in the device. These hard solders are not subject to the fatigue

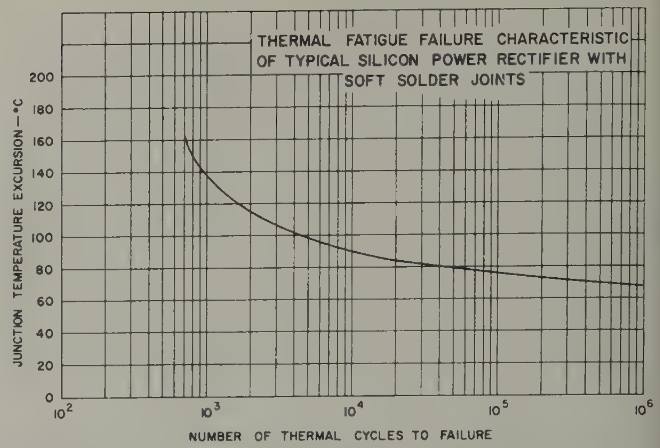

Fig. 1—Thermal fatigue failure characteristic of typical silicon power rectifier with soft solder joints.

phenomenon. A typical line of General Electric 25 ampere hard-soldered silicon rectifiers has been tested to 70,000 cycles of a 165°C temperature excursion without any measurable change in the thermal characteristics of its joints. This indicates that, with properly designed devices, thermal fatigue can be ignored as a threat to long term reliability. Such semiconductors can operate for extended periods right up to the manufacturer's maximum temperature and load current ratings without any need for the severe derating that has become commonplace for devices with soft solder joints.

In semiconductor devices with faulty hermetic seals, repeated temperature excursions will also cause such a device to "breathe," as the air or gas inside alternately contracts and expands. This action draws outside air with its associated moisture and contaminants into the housing, causing deterioration of device characteristics when the contaminants reach the junction surface.

Recurrent Load Current Ratings

Silicon rectifiers and controlled rectifiers, unlike tubes, are not emission limited. Thus, the current a rectifier can handle is limited only by thermal considerations. If a junction is uniform in its cross-section, the current distributes evenly across that junction. The power losses due to forward voltage drop across the junction create heat and raise the temperature of the junction above its surroundings. Provided the peak junction temperature does not exceed the maximum temperature rating of the semiconductor, the long trouble-free service predicted by the manufacturer's life test may be expected.

In cyclical applications at power frequencies, especially where the conduction angle in the cycle is relatively short, such as in multiphase or capacitive load operation, the peak junction temperature may swing as much as 20 to 30°C above the average temperature once each cycle. Therefore rating systems that consider average junction temperature rise rather than peak temperature are unrealistic in assessing the severity of the application, since they may subject a

cell to recurrent temperatures at which its characteristics have not been tested or guaranteed. Average junction temperature is the same as peak junction temperature only in pure d-c applications, a very limited case.

To determine peak junction temperature under cyclical or intermittent duty cycles requires a knowledge, not only of the steady-state thermal resistance characteristics of the semiconductor, but also of the transient thermal characteristics which define the ability of the device to store heat as well as transmit heat. A straightforward and easy-to-use means of portraying the transient thermal characteristics is shown in Fig. 2. This curve depicts the transient thermal resistance of a 25 ampere silicon controlled rectifier over six orders of magnitude of time. The ordinate of this curve is an apparent thermal resistance that defines the temperature rise per unit power dissipation of the junction above a reference point for a specified period of time after application of a step function of heat to the junction. It is assumed that the junction was previously at temperature equilibrium with the reference point. Thus, if 100 watts of losses are dissipated at the junction of the device described in Fig. 2, its temperature will rise 0.4°C/watt x 100 watts = 40°C in 0.01 second, and 1.0°C/watt x 100 watts = 100°C in 0.1 second.

Over a relatively narrow range of time, the transient thermal resistance curve can be represented by a simple time constant. However, contrary to the generally accepted practice, a single time constant cannot be used to accurately define thermal response of a junction over many orders of magnitude of time. The thermal paths in a semiconductor are a complex transmission line and cannot be accurately represented by a single lumped thermal resistance and a single lumped thermal capacitance.

By means of the transient thermal resistance curve, the data for which can be actually measured on specific semiconductor devices, the junction temperature response for both simple and complex duty cycles can be readily calculated. These rating techniques, which have been described in a previous paper[4], lead to current ratings applicable to any conceivable set of load conditions. Ratings so developed maintain peak junction temperature within limits that lead to reliable operation over extended periods of time.

In industrial rectifier equipment circles, semiconductor rectifier cells have in the past developed a reputation for poor overload capability compared to other types of power rectifying devices. Equipment designers were inclined to treat overloads in excess of a few cycles duration as a steady-state condition for semiconductors. This over-conservative approach was necessitated by lack of a sound rating philosophy for overloads, and in many applications this over-design therefore painted an unfavorable economical picture. The foregoing approach using transient thermal resistance yields realistic overload ratings under any set of conditions. Coupled with the downward trend in semiconductor prices, power semiconductors are now being economically and reliably used in applications with severe overload conditions.

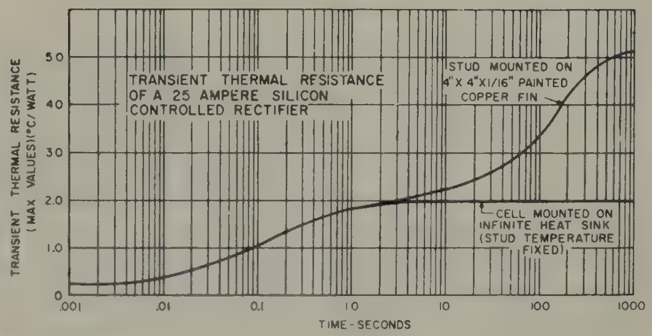

Fig. 2—Transient thermal resistance of a 25 ampere silicon controlled rectifier.

Non-Recurrent Load Current Ratings

In most practical applications of power semiconductors, the possibility of faults or exceptionally high overload conditions is remote, but still very real. For these types of non-recurrent overloads, the semiconductor manufacturer provides device ratings in the form of surge data and curves. To be readily useful to the circuit designer, surge ratings usually apply to a device that is already operating at its maximum recurrent load ratings. Thus, with the junction already operating at its maximum temperature rating, the surge elevates the junction temperature to a level well above its maximum recurrent rating. A typical one cycle surge rating may actually lift local junction temperatures to 500°C or even higher.

While it can be shown by tests that occasional short junction temperature excursions above the maximum ratings do not cause measurable damage to a well-constructed device, it is illogical to subject a semiconductor to this duty on a recurrent or regular basis without running the risk of reduced semiconductor life expectancy. Any semiconductor rating philosophy that permits *recurrent* overloads to raise the junction temperature above its maximum ratings is either acquiescing to reduced reliability, or is acknowledging that its maximum continuous temperature rating is unrealistically and inconsistently low. Surge ratings should therefore be used only for exceptional overload circumstances caused by such occurrences as short circuits and the failure of associated components in the circuit. As a rule-of-thumb guidepost to the meaning of "non-recurrent," it has been proposed that such an overload condition occurs no more often than 100 to 500 times in the life of the equipment. Stated another way, a semiconductor should be able to handle its non-recurrent surge ratings between 100 and 500 times without significant change in its characteristics.

A surge rating therefore defines what a semiconductor can handle without being damaged. It should be kept in mind that the semiconductor device, even

though it survives, may not be able to perform its normal circuit function immediately following the surge due to a temporarily high junction temperature which is well above its rating. While a rectifier should still block in the reverse direction immediately following a surge, its leakage current may be substantially above its guaranteed value momentarily. This may cause malfunction in associated circuitry such as magnetic amplifiers. A controlled rectifier may not block its rated forward voltage immediately after a surge due to temperatures above rated value. This might well lead to serious circuit malfunction, particularly in such circuits as reversing drives and inverters. Here then is another good reason why surge data should be used only for very unusual circumstances such as immediately preceding the blowing of a fuse, or the tripping of a circuit breaker. All normally expected overload and inrush conditions should be considered as recurrent loads and should be treated by the techniques described in the previous section.

Surge data on rectifiers and controlled rectifiers is usually presented in the form of a curve showing the peak current rating plotted against the number of half cycles on a 60 cps base that the device can withstand. The waveshape of the current is generally defined as a half sine wave. For other current waveshapes, conversion can conservatively be made on an r.m.s. basis. For overloads of less than one-half cycle duration, surge ratings are now often expressed in the form of an I^2t rating which applies to a range of time. I is in r.m.s. amperes and t is in seconds, and the rating is expressed as a certain value of amp-squared seconds. This kind of rating is particularly useful in co-ordinating the semiconductor with current-limiting fuse protection when the exact fault current waveshape is not known or too complex to calculate. As long as the interrupting I^2t rating of the fuse is less than the I^2t rating of the semiconductor, positive protection for sub-cycle faults is ensured.

Where Do We Go From Here?

Open discussion of rating philosophies and terminology in the trade journals and before technical meetings has resulted in a prolific exchange of ideas and a good deal of progress in achieving a logical and uniform system of characterizing and rating semiconductors. The IRE, JEDEC, and AIEE Standardization groups have been particularly active in formulating a systematized, consistent body of basic information in this area. But a great deal of hard work still remains to be done before the semiconductor user is spared some of the bewilderment and confusion of interpreting and comparing the inconsistent specification sheets on semiconductors of different type and manufacture.

Future technical progress in the rating of power semiconductors will move hand-in-hand with improvements in the processing and manufacture of the devices themselves. As the finished product becomes still more consistent and uniform in its mechanical and electrical characteristics, the rating of the devices can become an even more exact science. Prediction of life expectancy as a function of parameters like temperature, load, and voltage will become more meaningful and precise.

As reverse characteristics and modes of failure become better understood and better controlled, we may expect to see some of the techniques outlined here for forward load current rating extended to the blocking mode of operation. Not only avalanche regulators but also conventional rectifiers will be rated to dissipate very significant pulses of power in the reverse as well as the forward direction. New approaches will be developed for rating semiconductors for extremely short load and blocking pulses. These rating techniques, which must consider switching phenomena and dissipation as well as static characteristics, are becoming increasingly important for power semiconductors with the stepped-up use of these devices in ultrasonic systems, inverters, and radar circuits.

Perhaps the biggest single chore for highly developed semiconductor rating philosophies will lie in opening up the vast commercial and home markets to power semiconductors. Applications in home appliances and services, in automobiles, trucks and farm equipment, as well as in stores and other commercial establishments have one thing in common: besides functioning reliably, semiconductors must achieve rock-bottom costs to break into these markets. In high volume applications, semiconductors will be specially tailored for each type of job in order to avoid the wasted pennies of overdesign and excessive safety factors on the one hand, and marginal operation and questionable reliability on the other. What this basically means is that the semiconductor manufacturer will have to analyze and understand the use to which his semiconductor will be put better than in any industrial or military application where economics can tolerate abundant safety factors. He will have to interpret the application in terms of what the semiconductor will see, and then he must design, build, and test his semiconductor to do that specific job . . . . not a great deal more, and certainly not less.

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An Analysis of The D-C Design Considerations of a Transistorized Schmitt Trigger

Part 2

JACK CORSIGLIA*

In the design of a transistorized Schmitt trigger one can embark upon quite a tail-chasing episode if he expects to change only one parameter to achieve a desired result. Often a compromise must be reached between dead band, trip point, and swing in output voltage. In some instances another stage may be required to complete the desired function. A sound design approach is to establish first the necessary requirements, and second the desirable requirements. In this manner the number of variable parameters is minimized.

Changes in Parameters

Some discussion of the various parameters of the circuits and their effect upon the circuit is in order. The effect of varying R_1 on the operation of the circuit is to change both the upper and lower trip points, (Fig. 6), since this changes the voltage divider at the base of Q_2. This can also be seen from Equations 2 and 4. If R_1 is too large, I_B of Q_2 will be reduced to the extent that Q_2 will no longer be in saturation.

The effect of varying R_2 is to greatly change the upper and lower trip points (Equations 2 and 4), and with small values of R_2, to provide a smaller dead band. R_2 decreases the "off" current of Q_2 when Q_2 is "off" and Q_1 is "on," since it provides a d-c return for the reverse bias voltage across the base of Q_2 due to the voltage drop across R_E. The value of R_2, as shown in Fig. 7, also greatly affects the saturation voltage of Q_2. If a wide range in R_E is used, a small value of R_2 reduces the swing in output voltage Fig. 8. R_2 cannot be made small with regard to R_1. R_2, therefore, should be large with regard to R_1, and it can be found through experimentation that an optimum swing in output voltage can be obtained for a unique value of R_2. The total resistance of R_1 and R_2 should be large compared with R_{C1}.

The effect of varying R_{C1} upon the circuit is to change the upper and lower trip points with an increase in dead band for the higher values of R_{C1}, Fig. 9. The larger the value of R_{C1}, the greater will be the swing in output voltage, regardless of from which collector the output is taken. R_{C1} has a definite limitation in that it cannot be too small for a wide range in emitter resistance without incurring a loss in saturation of Q_2. Therefore, R_{C1} should be as large as possible and still provide good base drive for R_1 and R_2, and also be consistent with the frequency requirements.

The effect of R_{C2} on the circuit is to affect only the

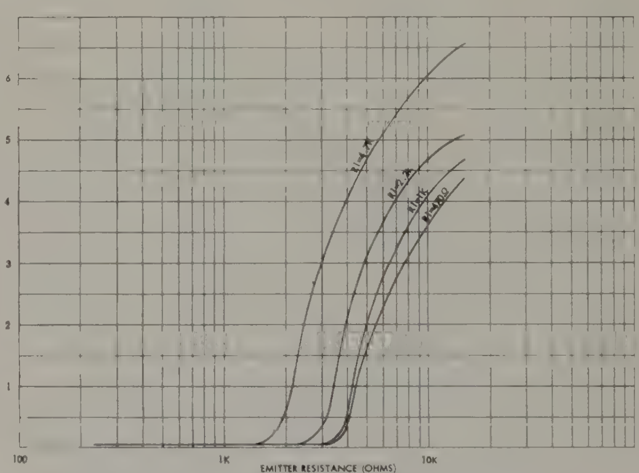

Fig. 6—Variations of R_1 for V_{CE} versus R_E.

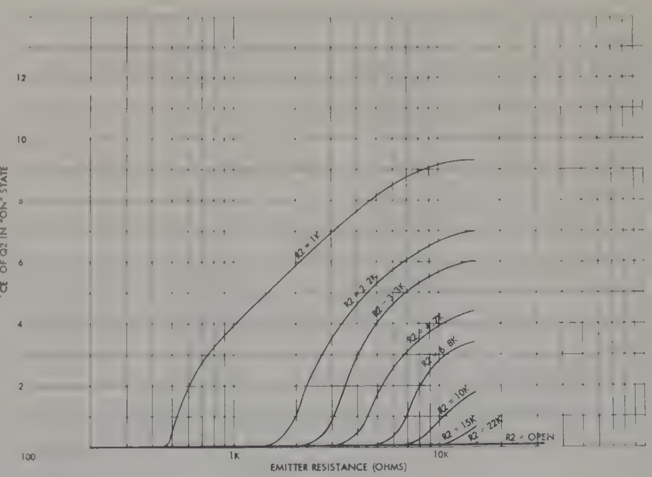

Fig. 7—Variations of R_2 for V_{CE} versus R_E.

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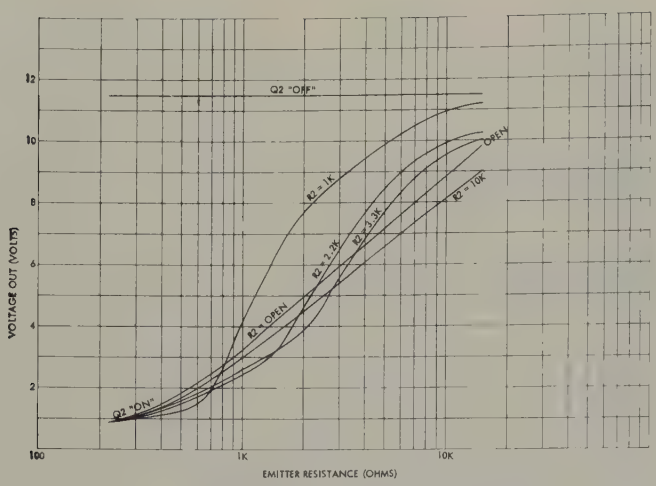

Fig. 8—Variations of R_2 for V_0 versus R_E.

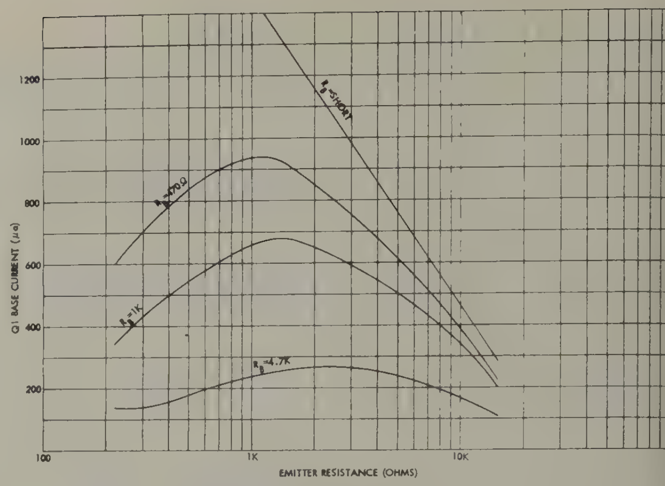

Fig. 11—Variations of R_B for I_{B1} versus R_E.

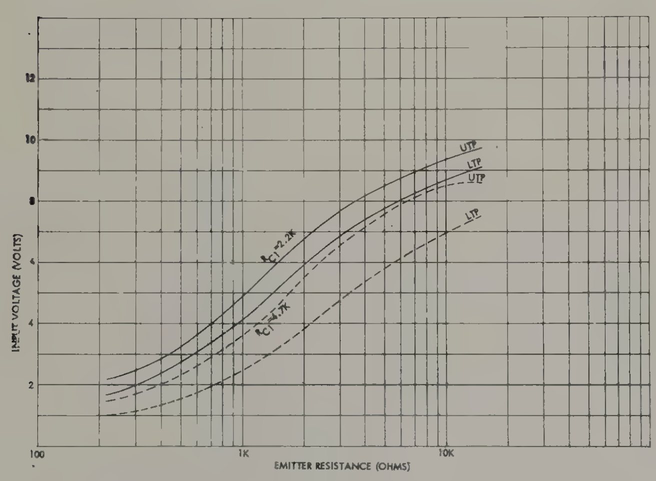

Fig. 9—Variations of R_{C1} for V_{in} versus R_E.

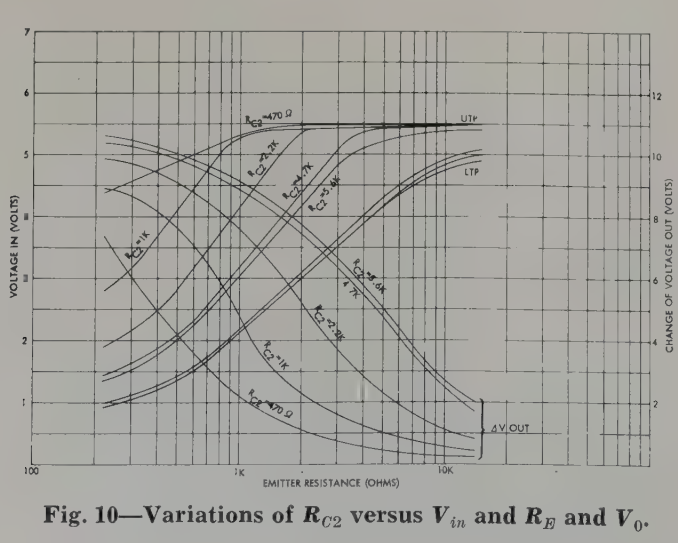

Fig. 10—Variations of R_{C2} versus V_{in} and R_E and V_0.

upper trip point, Fig. 10. There is an obvious increase in dead band for the smaller values of R_{C2}. Again, the larger the value of R_{C2}, the greater the output voltage swing and the lower the saturation voltage of Q_2 will become. Therefore, R_{C2} should be as large as possible and yet be consistent with external loading and frequency response requirements.

The variation of R_B upon the circuit has essentially no effect upon the trip point or dead band, or the d-c points of operation of Q_1 and Q_2. As shown in Fig. 11, its purpose is mainly to limit the input impedance and to provide a high frequency peaking circuit by employing a "speed-up" capacitor in parallel with R_B.

The effect of decreasing the load resistance from the collector of Q_1 to ground reduces the output swing (output from collector of Q_2), but does not affect the d-c level of the output voltage when Q_2 is "off", as can be seen in Fig. 12.

The effect of decreasing the load resistance from the collector of Q_2 to ground is to reduce the swing in output voltage, (Fig. 13). Obviously, if R_L is equal to R_{C2}, the maximum output voltage swing that could possibly be obtained is one-half the supply voltage. Further, any decrease in load resistance decreases the dead band, (Fig. 14), and limits the region of operation in which bistable operation can be maintained, before the loop gain drops below unity, and linear amplifier action begins. As the loop gain decreases toward unity, one would expect the dead band to decrease, as shown in Fig. 4. Therefore, there is a definite limit as to the amount of loading which can be allowed on the collector of Q_2. The additional loading on the collector of Q_2 drastically lowers the upper and lower trip points and tends to distort the dead band distribution for a wide range in trip settings. The effect of loading is more severe upon the circuit operation when the circuit is loaded at the collector of Q_2 than it is when at the collector of Q_1. For these reasons, it is desirable to feed the output of a Schmitt trigger into an emitter follower, which presents a low loading effect, due to its high input impedance.

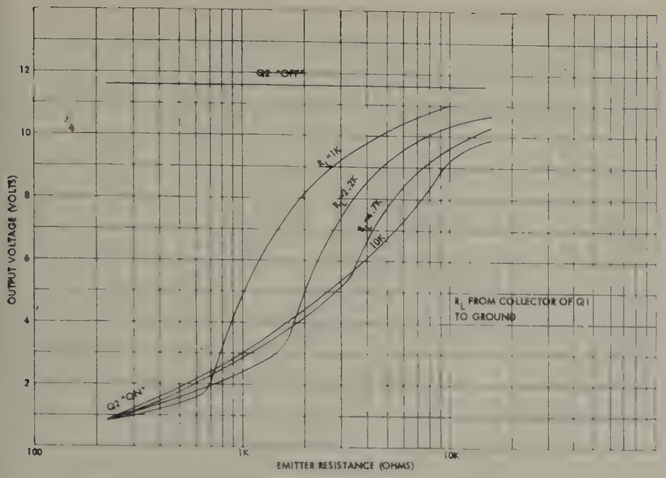

Fig. 12—Variations of R_L for V_0 versus R_E.

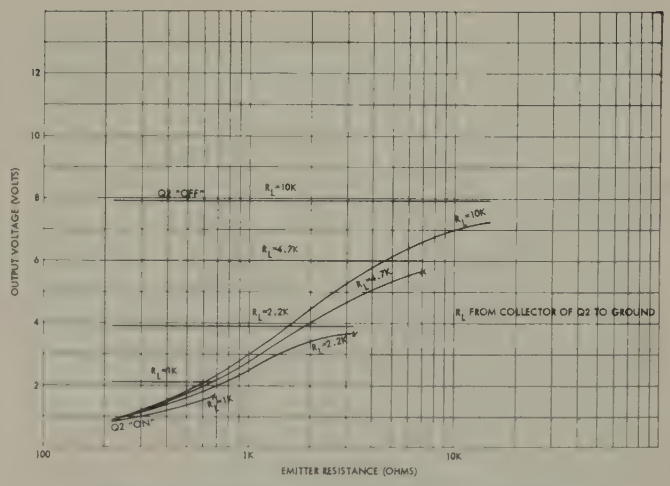

Fig. 13—Variations of R_L for V_0 versus R_E.

The effect of variation of these different parameters upon the circuit in Fig. 3 is summarized in Table II; e.g., for an increase in resistance in R_{C1}, the effect upon the rest of the circuit is to: decrease the collector current of Q_1 when it is "on," decrease the voltage from emitter to collector of Q_1 when it is conducting, increase the collector current of Q_2 when it is "on," etc. A "change" can be interpreted as approximately 20 percent or more. The output voltage is taken from the collector of Q_2.

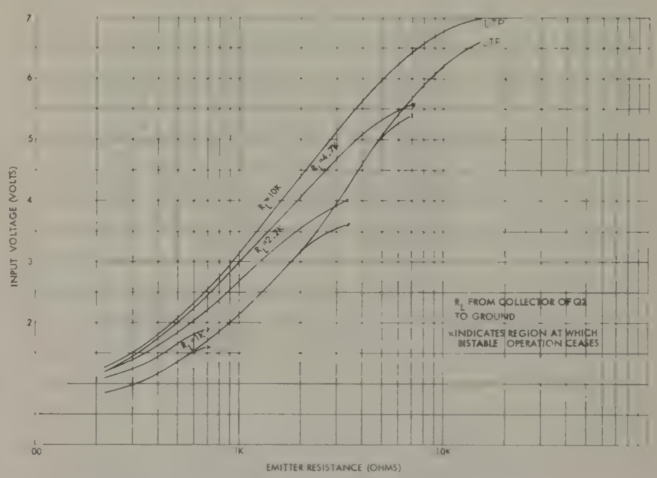

Fig. 14—Variations of R_L for V_{in} versus R_E.

Adjusting the Dead Band

In Fig. 15, a circuit is shown for a silicon transistor Schmitt trigger which has an upper trip point of 6.6 volts, a lower trip point of 5.5 volts, and an output swing from 0 to 15 volts. In this circuit, the Zener diode, D_2, reduces the collector level of Q_1 in its "on" state from 9 volts to 0 volt. This gives the advantage of a 15-volt swing in output voltage, referred to ground. It should be noticed that R_1 has been replaced by a diode D_1, and resistor R_3. This network forms a current limiting device which presents a very high input impedance from Q_1. If the input voltage should ever exceed 25 volts, the diode D_1 would be reverse biased. This prevents the V_{EB} of Q_2 from being exceeded. It should further be observed that R_{C2} has diminished to zero ohms. This permits Q_2 to act as an emitter follower, and give a good feedback coupling into the emitter of Q_1 and at the same time, presents

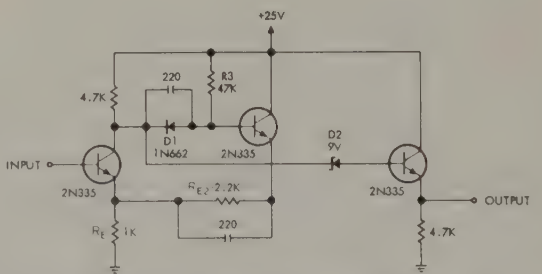

Fig. 15—Silicon transistor Schmitt trigger circuit with a zero volt output reference.

Table II

Increase Resistance of Parameter	I_C Q_1 ON	V_{EC} Q_1 ON	I_C Q_1 OFF	I_C Q_2 ON	V_{EC} Q_2 ON	I_C Q_2 OFF	LTP	UTP	Vo	Dead Band
R_{C1}	D	D	NC	I	NC	NC	D	D	SD	I
R_{C2}	NC	NC	NC	D	D	NC	NC	D	I	D
R_E	D	I	D	D	I	D	I	I	D	NC
R_1	NC	NC	I	NC	I	SD	D	D	NC	D
R_2	I	SI	NC	NC	D	I	I	I	I	I

NC = Negligible Change D = Decrease SD = Slight Decrease
I = Increase SI = Slight Increase

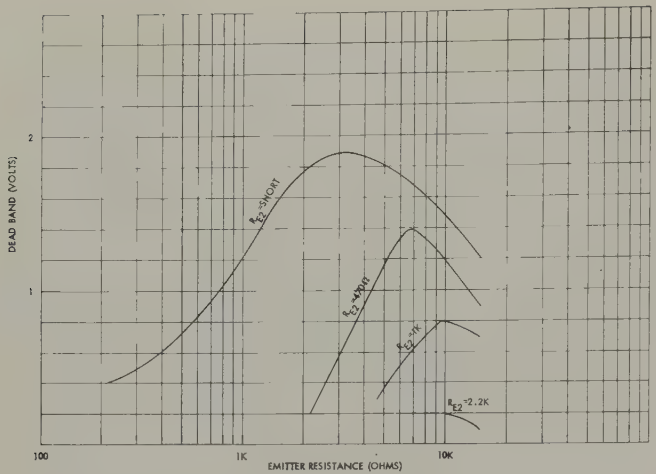

Fig. 16—Variations of R_{E2} for deadband versus R_E.

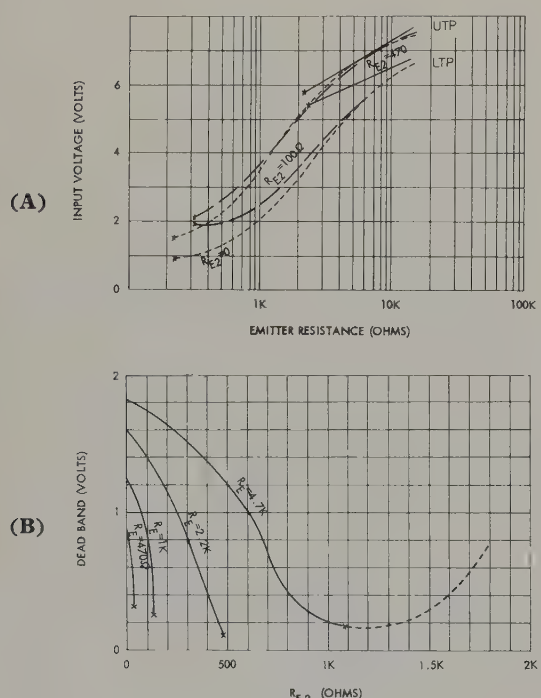

Fig. 17—Deadband and stability variations for R_E versus R_{E2}.

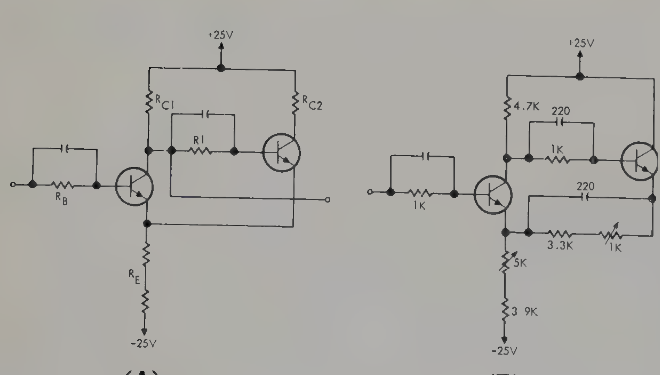

Fig. 18—Silicon transistor Schmitt trigger circuit with a trip point below zero volts.

a very light load on the collector of Q_1. Since the output is taken from the collector of Q_1, R_{C2} does not affect the swing in the output voltage. The omission of R_{C2} further serves to decrease the off current of Q_1 and Q_2. There is, however, a slight increase in dead band. General circuit operation is improved by decreasing R_{C2} when R_{E2} is increased. R_2 has been omitted in this circuit since these are silicon transistors and I_{CBO} does not present as great a problem as with germanium. The omission of R_2 makes possible a greater swing in output voltage at the expense of increasing the dead band, and raising both the upper and lower trip points.

The addition of R_{E2} in series with the emitter of Q_2 gives a control of the upper trip point without affecting the lower trip point. When Q_2 is "off," R_{E2} has no effect on the circuit since the collector current in Q_2 is zero and will only affect the circuit when Q_2 is "on." A potentiometer could be inserted to provide an adjustment of the upper trip point and, consequently, the dead band. If R_{C2} is not reduced when R_{E2} is increased from zero ohm to a finite value, there will be a definite limit upon the amount of resistance which can be added in series with the emitter of Q_2 and still maintain bistable operation.

For a fixed value of R_{E2} there exists a maximum dead band for a unique value of emitter resistance (Fig. 16). However, the dead band cannot be minimized in this same manner because the closed loop gain will drop below unity, (Fig. 4). Further, the swing in output voltage is greatly reduced with an increase in R_{E2} since a larger emitter resistance is mandatory in achieving good bistable operation.

As can be seen from the curves in Fig. 17 (these curves are taken from the circuit shown in Fig. 3), the maximum resistance for R_{E2} is dependent upon the value of R_E and R_{C2}. An increase in R_{E2} will reduce the dead band to a definite limit which will be reached when the loop gain drops below unity. The effect of too large a value of R_{E2} is observed by the circuit operating as a linear amplifier. This is indicated on the curves in Fig. 17 by an "x", which indicates that bistable operation can no longer be obtained for a further change in value of R_E. Thus, it is again seen that a small amount of dead band is essential for good bistable operation of the Schmitt trigger circuit, (Fig. 4). The larger the value of R_{E2}, the higher I_{C2} must be to maintain the loop gain above unity. Therefore, the smaller R_{C2} and R_E must be to provide the same minimum amount of current through Q_2.

Thus, a minimum dead band can only be approached as a limit, with a compromise given between minimum dead band and still ensure bistable operation. If R_{C2} is reduced to zero, there is a minimum value of resistance for R_{E2} which can be used before the loop gain again drops below unity. Thus, the dotted line portion of the right hand curve in Fig. 17B is the stable region of operation, and the solid part of the curve becomes the region of linear amplification, when R_{C2} is omitted.

In order to achieve trip points which are close to zero or which may be above or below 0 volts, the circuit in Fig. 18A was investigated. One of the principal disadvantages of this circuit was that the dead band was 8 volts and that the upper trip point was not low enough. In an effort to reduce the dead band, R_{E2} was introduced. In attempting to reduce R_{C1} below 4.7K, the loop gain fell below unity. When this occurs, the output is a similar representation of the input instead of a binary output (see Fig. 4). Any increase in R_{C1} only resulted in increasing the dead band.

These changes resulted in the circuit of Fig. 18B, which gave a dead band operation from 0.2 to 2.7 volts, depending upon the value of R_{E2}. This circuit had a trip range for the upper trip point from —1 to +8 volts with higher trip settings up to 10 volts possible at the sacrifice of a wider dead band.

The circuit in Fig. 19 is a modification of the circuit in Fig. 18B. In the circuit of Fig. 19, R_1 has been replaced with a current limiting device of D_1 and R_3. This resulted in an increase in the dead band of 0.6 volt, making a total minimum dead band of 0.8 volt. In order to obtain a rapid change of state (loop gain above unity), and still provide a minimum dead band, it was found that the minimum value of R_{E2} for the circuit in Fig. 19 must be 3.3K. (See Fig. 17.) If an adjustment of dead band is not required, the 1K potentiometer in series with the emitter of Q_2 can be eliminated. The binary output corresponding to the lower trip point is quite constant throughout the range of trip settings. However, the binary output corresponding to the upper trip point has a variation of 7 volts throughout the trip range. (See curve in Fig. 20A.)

As can be seen from the curves in Fig. 20B, this circuit has excellent stability with temperature ranges from —20°C to +80°C. The total deviation in the binary output corresponding to the upper trip point is 0.4 volt, which represents roughly a 4 percent change. The deviation of the binary output corresponding to the lower trip point is 0.6 volt. The voltage at which the upper trip point will occur is constant within 0.1 volt, which maintains an accuracy of about 2 percent. The deviation of the lower trip point is the greatest of all voltage variations, which measured 0.9 volt.

Acknowledgements

Sincere thanks and appreciation are extended to Harry Hill, John Miller, George Sculley, and Don Filan for their help and cooperation in the above tests and development work.

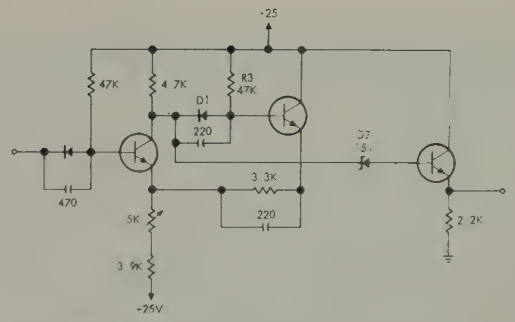

Fig. 19—Silicon transistor Schmitt trigger circuit with a zero volt output reference and a trip range from —4 volts to +8 volts.

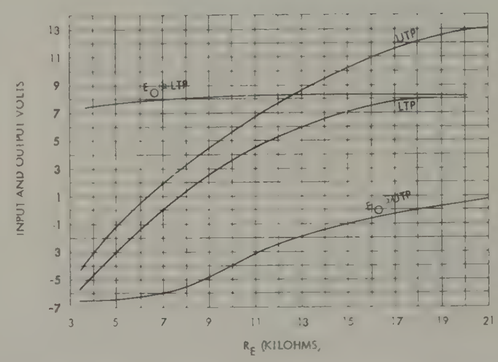

Fig. 20A—Variations of trip point and output voltage for input voltage versus emitter resistance.

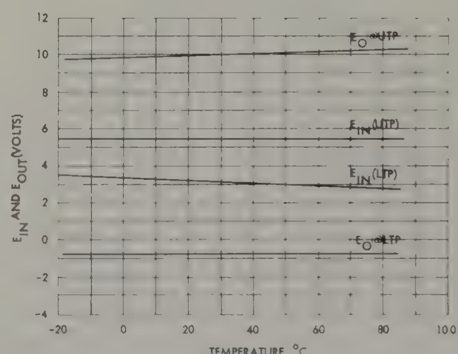

Fig. 20B—Variations of trip point for input voltage versus temperature.

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The Technology of Pulling Single Crystals

HENRY T. MINDEN*

Part 2.

Thermal Design

There are many possible pitfalls in the design, construction and operation of a crystal puller. Some of them have been mentioned already. Others occur to the great puzzlement of operators and engineers, who are often unaware of any defects in their apparatus. Granted that they are minimized in a neatly designed puller, they still crop up quite frequently in jury-built experimental units. It is the author's belief that many defects in puller design can be quickly detected and analysed, if at the outset care is taken to provide the operator with a very clear view of the liquid-crystal junction. Large windows which permit a wide range of sighting angles are very desirable. A wide crucible is helpful, although too wide a crucible may cause the freezing isotherm to become excessively flat. Since the operator must usually stand "in front" of the puller, rotation of the seed and crucible gives him a clear view of what is happening around the entire growing interface. The main purpose of all the precautions is to permit the operator to observe *in situ* the nature of imperfect crystal growth.

Sometimes ingots become polycrystalline, if they grow beyond a certain diameter. This occurence can be a source of great mystification, and elaborate theories may be invoked as explanation. More often than not the onset of polycrystallinity is caused by the fact that the axis of the dish-shaped freezing isotherm does not coincide with the crucible axis. The freezing isotherm may even be unsymmetrical. This effect is shown in Fig. 8. One side of the melt surface is below the melting point and a polycrystalline solid shelf freezes partly across the melt. Fig. 9 shows the melt surface in perspective with the crystal growing at a small diameter. As the crucible temperature is lowered to increase the crystal diameter, the shelf will grow towards the center. The circumference of the crystal reaches the shelf; polycrystalline debris is picked up on the rim of the freezing interface, and new crystals will be nucleated on the ingot. In an extreme case the crystal will freeze solidly to the shelf, causing either the seed to snap or the crucible to break.

The reason that the shelf formation is not readily detectable is the fact that the operator is often unable to see clearly the rim of the melt. If the melt

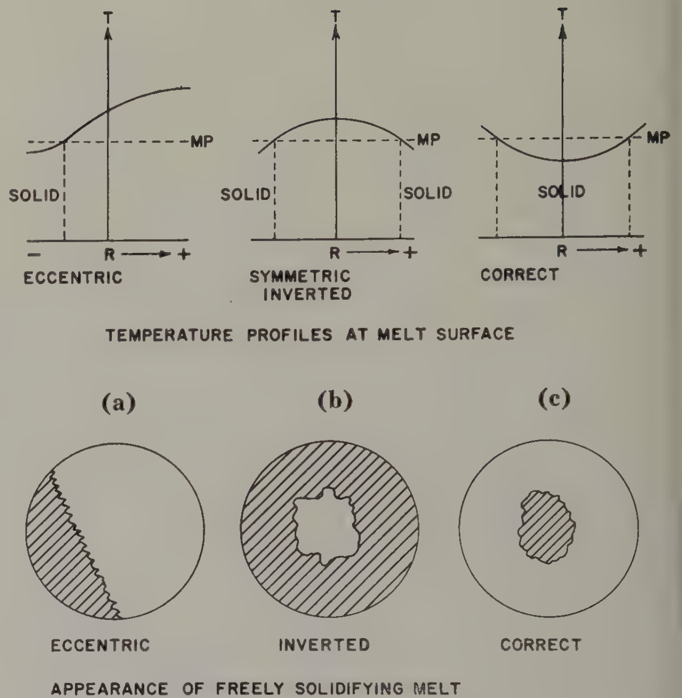

Fig. 8—Unsatisfactory thermal conditions at the melt surface. (a) Assymmetric freezing isotherm showing freezing from one side. (b) Inverted freezing isotherm, showing symmetric shelf formation. (c) Correct dish-shaped freezing isotherm showing centrally located solid island.

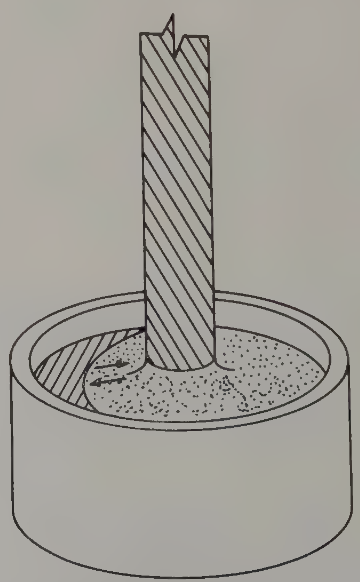

Fig. 9—Perspective view of growing crystal approaching the solid shelf.

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surface is well below the edge of the crucible, the operator may not be able to see even the freezing interface. It is no wonder then that the occurrence of polycrystallinity may seem like an uncontrollable artifact.

Obviously then the heater must be very carefully made and the crucible must be accurately centered in order to insure that the temperature profile is symmetrical. A difference of as little as one degree C across the usual size crucible can give rise to shelf formation. It is extremely difficult to design and build heaters to the close tolerances required. Even an initially symmetrical resistance heater in time is apt to become unsymmetrical.

A somewhat simpler method of insuring an effective symmetrical isotherm is to rotate the crucible within the heater. In this way all portions of the crucible are subject to the average thermal effects of all parts of the heater. It is also wise to rotate the crystal; in fact this is almost universally done—more so than the rotation of the crucible. If the crystal is not rotated, then it too may become unsymmetrically heated. The effect of asymmetrical crystal temperatures is not nearly so drastic as that of shelf formation, however. The crystal will merely tend to grow towards its coolest side so that its axis will be bent. If this effect is too extreme, of course, the crystal may hit and freeze to the side of the crucible.

Even though the crystal is rotated, the freezing isotherm may be incorrect. Fig. 8 shows the effect of an inverted isotherm. In this case, the shelf forms symmetrically around the side of the crucible. The symmetrical shelf will occur if induction heating is used on the melt itself. The outside of an induction heated melt is usually cooler than the center. This is due to the radiation loss at the side surface of the melt. It is always wise where possible to use a graphite crucible with induction heating. The crucible acts as a susceptor and yields the thermal configuration of a resistance heater. If a graphite crucible cannot be used as in the case of silicon, the quartz crucible should be surrounded by a graphite susceptor.

The growing crystal itself alters radically the shape of the freezing isotherm. Under the crystal the freezing isotherm lies along the liquid-solid interface. The configuration of the interface depends on the magnitude of the sources and sinks of heat. Heat arrives at the interface through the liquid from the external heater. Another source is the heat of fusion generated along the interface. Heat is lost upward by conduction through the crystal and by radiation from the cylindrical surface of the crystal. Radiation loss tends to cool the periphery and gives rise to a concave freezing interface, as shown by the ridges in the flat in Fig. 7. See Part 1. This loss can be suppressed by the use of an auxilliary heater just above the melt and also by having the melt surface deep in a narrow crucible. In any case, the radiation loss rate decreases drastically ($\propto T^4$) as the temperature decreases.

On the other hand, conduction heat loss cools the

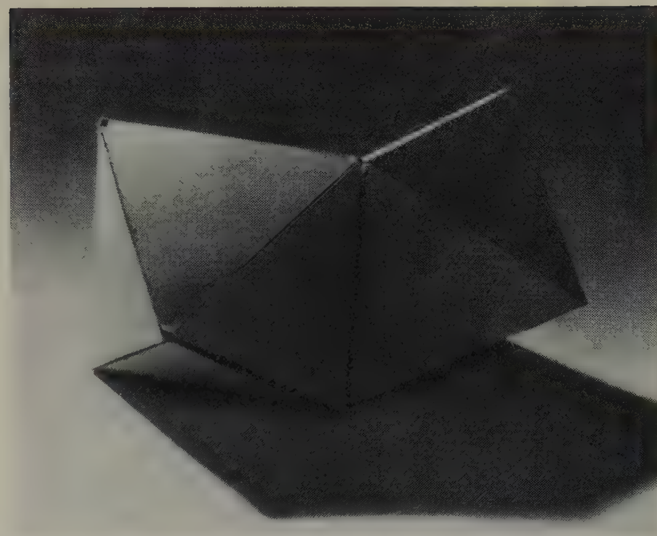


Fig. 10—Schematic diagram of a twinned diamond type crystal. The original (111) oriented lattice is on the left, while the twinned (100) oriented lattice is on the right.

center of the crystal and tends to make the interface convex. The rate of conduction loss varies more or less linearly with temperature. For a given crystal puller lower melting materials will tend to grow with a convex interface. For example silicon (mp 1400°C) may have a concave interface, germanium (mp 940°C) a nearly flat one, while InSb (mp 535°) may have a convex one.

One way of altering the ratio of radiation to conduction loss is to alter the crystal diameter. The radiation loss for a crystal length dl is proportional to $2\pi r dl$, while the conduction loss is proportional to $\pi r^2 dl$. For a high melting crystal, increasing the diameter tends to straighten out a concave interface while in a low melting crystal, decreasing the diameter tends to straighten out a convex interface.

As will be discussed below, it is desirable to have a nearly flat freezing interface. It should be apparent that there are many variables which can be adjusted to secure a proper freezing condition. Suffice it to say, however, that in a given puller once the conditions have been found for one material, it does not necessarily follow that no alterations are required for other materials.

Imperfect Growth

It is well known that a regular crystal lattice is an idealization which is not achieved in nature. Even the most perfect crystals will inevitably contain point defects. These are lattice vacancies,[6] interstitial atoms, and foreign atoms. Moreover, point defects can cluster. Most semiconductor crystals will also contain dislocations; these are structures resulting from the displacement of whole lattice planes. Special techniques[7,8] have been developed to grow dislocation free crystals. Whole crystal regions are mismatched at grain boundaries. If the grain boundary is such that the lattices on either side are mirror images, the

Fig. 11—Arsenic doped germanium crystal. Polycrystallinity at the bottom is caused by excessive arsenic in the melt.

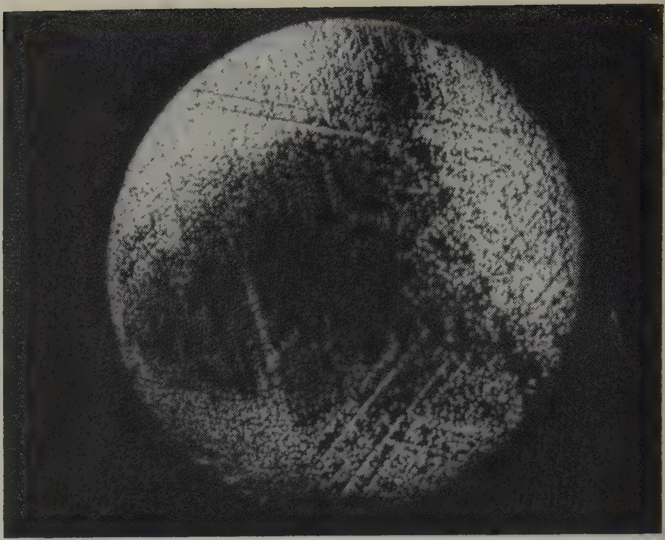


Fig. 12—Etch pit pattern on a cross section of a silicon crystal pulled in the (111) direction.[8] ***(Courtesy of S. J. Silverman)***

crystal is said to be twinned. Fig. 10 shows a model of the common [111] twin plane by means of which growth shifts from the (111) direction to essentially a (100) direction. Twin formation in semiconductors is a very low energy process and occurs quite readily during the growth of semiconductor crystals. Finally, a crystal lattice may even be distorted over a macroscopic region, giving rise to a phenomenon called lineage. It is not the object of this paper to discuss the detailed mechanisms of imperfect crystal growth.[9] Rather the technological artifacts causing imperfect growth will be pointed out.

The seed itself is the most obvious source of imperfection in the grown crystal. Twin boundaries and dislocations in the seed will be propragated unless special precautions are taken. These generally involve necking down the crystal to a very small diameter[7] during the initial phase of the growth. In this way the imperfections will be made to terminate at the surfaces of the crystal. It is best, of course, to start with a good seed, and such seeds are carefully husbanded in crystal growing facilities. In this connection it is worthwhile to note that single crystal growth occurs more easily in some orientations than in others. For instance, the (111) direction is preferred for germanium and silicon while the (113) direction[10] is preferred for the III-V compounds.

Impurities play an important role in determining the perfection of the crystal. Of course, the impurities themselves are defects whether they are wanted or not. In addition, impurities affect the crystalline perfection of the crystal. The incorporation of impurities may cause lattice distortion which leads to dislocation formation and twinning during the growth process. This occurs especially if the growth rate is too fast, because the concentration of rejected impurities builds up at the freezing interface. The growth of heavily doped crystals for tunnel diode use presents an extreme case of the effect of impurities. Fig. 11 shows an arsenic doped germanium crystal which became polycrystalline after the arsenic concentration in the melt was abruptly increased. It is a rule that for a given thermal gradient at the freezing interface slower growth rates are required for doped crystals than for pure crystals.[11]

It has recently been shown that if crystal growth occurs on a flat crystal facet the segregation of impurities is a lot poorer[11] than it is off the facet. This can lead to large lateral inhomogeneities in impurity concentration. To inhibit facet formation it has been suggested that seeds be oriented slightly off the desired crystallographic axis.

In crystal pulling the interface tends to be concave towards the melt. As the crystal is withdrawn from the melt, the cooler exterior will contract with respect to the interior of the crystal. Near the melting point semiconductor crystals are quite plastic, so that the energy of deformation is small. As the crystal cools inhomogeneously, strains are set up, and the crystal will deform along slip planes with consequent production of dislocations. The etch pattern formed by such a structure is shown in Fig. 12.

Crystal growth occurs by means of two dimensional nucleation on crystallographic planes. In general, a nearly planar interface is required so that growth will occur on the same crystallographic planes throughout the whole area of the interface. If the interface has an excessive curvature, nucleation will occur on different planes across the interface. The twin energy in semiconductors is so low that the crystal will twin during growth in such a way that for each twin a preferred nucleation plane will conform to the freezing interface.

The interaction of a twin plane with a curved freezing interface will give rise to a situation in which the production of multiple twins will occur. In Fig. 13a, the twin plane is shown intersecting the growth surface. As the crystal grows the twin plane

becomes tangent (Fig. 13b) to the curved interface. Since the crystal has already grown in its original orientation beyond the point of tangency, the twin plane cannot propagate any further. On the other hand the crystal is already growing in two different orientations on either side of the tangent point. In order to accommodate the different orientations growing side by side, a new set of multiple twins will form as shown in Fig. 13c. Excessive twinning is usually the precurser of lineage and polycrystallinity. When a network of twin planes intersect randomly, mismatched grain boundaries almost inevitably occur.

The engineer and operator must always be on the lookout for chronic artifacts in the crystal puller which cause imperfect growth. Obviously the seed should receive careful scrutiny. The growth rate and doping level should be controlled. It is important to adjust the thermal configuration of the melt so that the interface is nearly planar. The shape of the interface during growth can be determined by abruptly pulling the crystal free of the melt. In the absence of the growing crystal, the dish-shaped freezing isotherm should have as large a curvature as possible. With care in the design and operation of a crystal puller it is readily possible to grow reasonably defect free crystals in a very reproducible manner.

Compound Semiconductors

The principles which have been discussed so far apply generally to the crystal pulling technique. These principles can be applied directly to the crystal growth of germanium, silicon, indium antimonide, etc. On the other hand there are many other substances such as gallium arsenide, indium arsenide, and cadium telluride which decompose upon melting. Generally these substances have one or more volatile components which distill from the melt and condense on the cool surfaces of conventional pullers. During the past few years, techniques have been developed to supress the decomposition. Meanwhile, other effects have been noticed which are attributable to the volatile nature of this melt. In this section some of the basic problems will be discussed, and a few technological details will be given. Gallium arsenide will be used as a convenient (and timely) example.

Gallium arsenide has a vapor pressure of close to one atmosphere[12] at its melting point. The vapor consists almost exclusively of As_4 molecules. As the liquid freezes in the presence of the vapor, there are three phases present. The system has two components, gallium and arsenic. Gibb's phase rule is

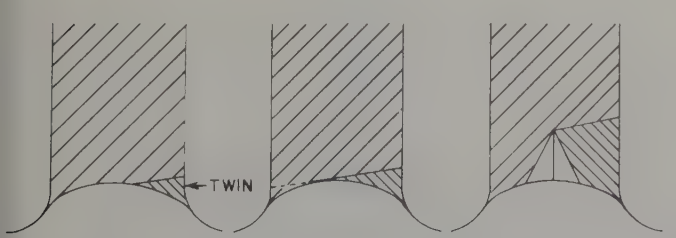
$$F = C - P + 2$$

where F = the thermodynamic degree of freedom of the system,

C = the number of components

P = the number of phases

For this system, then, there is only one degree of freedom. If the arsenic pressure over the melt is specified, the composition of the melt, the composition of the solid, and the melting point are all uniquely determined.* Now it is a fortunate characteristic of the common III-V compounds that the stoichiometric solid freezes even when the liquid is considerably off stoichiometry. Experimental evidence indicates that the deviation from stoichiometry in gallium arsenide is less than 1 part per million. Actually this question is currently the subject of considerable investigation, but the details are not relevant to the present discussion. The essential point is that depending on the arsenic pressure, the melt composition and the melting point can be varied over a wide range. Table 1 presents the data for gallium arsenide.[12] It will be seen that the vapor pressure of gallium arsenide at its maximum freezing point (1238°C) is .9 atm. Pure



a. b. c.

Fig. 13—Condition for the formation of multiple twins.

* This situation is similar to that encountered in the germanium arsenic system when heavily doped material is required. In the case of germanium, however, the arsenic concentration in the solid phase can be widely varied by detectable amounts.

Table I

P-T-x_L values of the three-phase line compound-liquid-vapor in the system Ga-As[12].

T_1(°C) (As)	P_{As} (atm)	Melting point(T_3) (°C)	Arsenic content of of the liquid (x_L) estimated from the data of Köster and Thomas [4]) (atom-%)
386	$6{\cdot}2.10^{-3}$	781 ± 20	7·5
438	$1{\cdot}8.10^{-2}$	895 ± 20	10·5
485	$5{\cdot}2.10^{-2}$	1068 ± 10	19
492	$6{\cdot}05.10^{-2}$	1055 ± 3	18
508	$8{\cdot}9.10^{-2}$	1085 ± 5	20·5
532	$1{\cdot}55.10^{-1}$	1181 ± 3	31
543	$2{\cdot}01.10^{-1}$	1190 ± 3	33
562	$3{\cdot}2.10^{-1}$	1196 ± 3	34·5
569	$3{\cdot}8.10^{-1}$	1221 ± 3	38
600	$7{\cdot}6.10^{-1}$	1234 ± 3	46
616	1·18	1235 ± 4	55
645	1·95	1231 ± 4	57·5
673	3·35	1205 ± 5	64·5
711	6·6	1185 ± 5	68
810*	$2{\cdot}9.10^{1}$	810	100

*Degenerate eutectic point. The As pressure at this point is practically equal to the vapor pressure of pure As at this temperature.

arsenic has this vapor pressure at 610°C. If solid (stoichiometric) gallium arsenide is melted in a conventional crystal puller, arsenic vapor is given off and expands to fill the chamber. Where the arsenic gas at .9 atm comes in contact with the walls of the chamber (which are at room temperature) the gas will condense, since the arsenic vapor pressure at room temperature is negligible. Assume that the temperature of the coldest spot in the chamber is raised. The vapor pressure of the arsenic from this spot will increase and the net rate of transfer of arsenic from the crucible to the cold spot will be decreased. When the temperature of the coldest spot (the so-called cold sink) reaches 610°C, the evolution of arsenic from the melt will be just balanced by the sublimation from the cold sink, and the melt will no longer decompose. It is on the basis of this experimental situation that process equipment for volatile compounds is designed.

Figure 14 is a schematic diagram for a so-called magnetic crystal puller.[13] It is essentially a sealed quartz tube at the bottom of which rests the crucible with the melt. A pull rod has a chuck which holds the seed; at the upper end of the rod is an encapsulated iron slug. In order to maintain the tube at the proper temperature (~610°C), it is enclosed in a furnace system. The magnets, however, must be kept outside the furnace because of their low Curie point. The magnets are moved up and down by a conventional pulling mechanism. Some provision must be made for viewing the melt. One satisfactory arrangement is to have a small window portion of the tube covered by a bare wire heating element. The heat from this element plus the radiation from the crucible suffice in a well designed puller to bring the window temperature above 610°C. The furnaces are so arranged that there is a control thermocouple at the coldest part of the tube. Sometimes a reentrant cavity may be provided, but more often a small sidearm with a separate furnace acts as the cold sink.

The magnetic puller is extremely awkward to use. It is not demountable, so that fairly elaborate quartzwork is required for each run. The weight which can be supported by the magnetic suspension is small, and the pulling motion is far from smooth. The demountability and drive system of a conventional puller is most desirable. But the O-rings, gaskets, and metal parts of the usual pullers will not stand up under the action of hot arsenic vapors, and even if they did, the hot metals would probably contaminate the melt.

Quartz and graphite, however, are not attacked by arsenic, and a syringe type positive bearing[14] has been designed (Fig. 15). A length of quartz tube is precision ground on the inside. A high purity graphite piston is machined to fit snugly into the quartz cylinder. The seed chuck is at one end of the piston, while the other end of the piston is attached to the pulling shaft. A furnace serves to suppress the melt decomposition, and a side-arm cold sink is used. The large

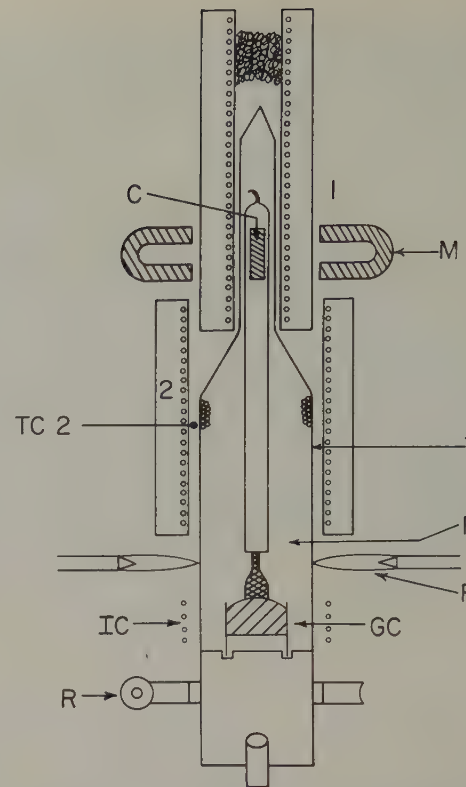


Fig. 14—Schematic diagram of a magnetically coupled crystal puller. "C" is a quartz encapsulated iron slug for suspending crystal at the end of the pull rod ("PR"). "R" is a rotating mechanism for the whole tube. The cold sink is at "TC2" and the flames "F" keep the "windows" clear.

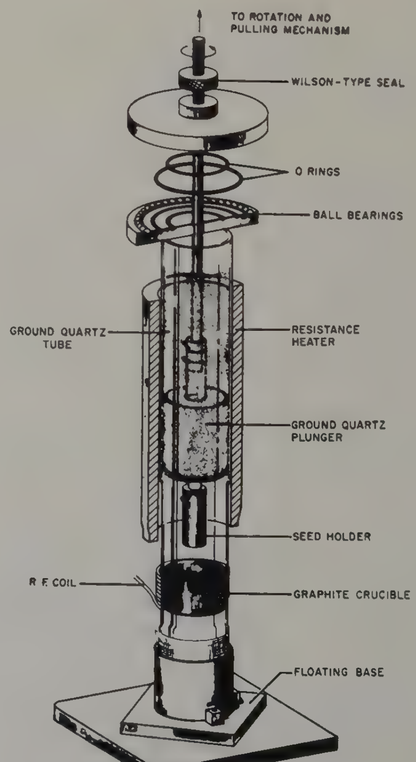


Fig. 15—Schematic diagram of a syringe type crystal puller.

furnace serves an additional purpose. Graphite has a higher coefficient of expansion than quartz. As the piston is heated, the clearance between the piston and cylinder decreases. The dimensions are made such that at a convenient temperature in excess of 610°C the clearance is sufficiently small to prevent excessive arsenic leakage; of course, the temperature of the piston must be held low enough to prevent binding. Even though the syringe type puller is fairly convenient, it will not support a high vapor pressure without excessive leakage. As a result substances like InP, GaP and heavily doped GaAs cannot be handled too readily in this system.

Since stoichiometric gallium arsenide will still crystallize from a nonstoichiometric melt, the need to hold the arsenic vapor pressure at .9 atm is not immediately apparent. It is tempting to try to grow gallium arsenide from a gallium rich melt. For instance, gallium arsenide crystallizes at about 1050°C from a 20% solution of arsenic in gallium; moreover, the arsenic pressure is only about 25 mm. Under these conditions gallium arsenide crystals could conceivably be grown in an open system.

In practice, however, nobody has been able to pull a single, untwinned crystal from a nonstoichiometric melt. As soon as the melt gets slightly off stoichiometry, extensive twinning takes place as shown in Fig. 16. If the melt is far off stoichiometry the ingot becomes polycrystalline and free gallium is included in the grain boundaries. The mechanism for this effect is not well understood, but it is undoubtedly related to the pile-up of rejected, excess gallium at the freezing interface. The polycrystallinity and twinning does become less extensive as the growth rate is decreased, but at practical pull rates (½″/hr) the ingot is always twinned. The effect is so striking that an operator can use it as a sign that the arsenic cold sink temperature is incorrectly adjusted.

There seems to be a lag between the time the cold sink temperature is changed and the time the stoichiometry is affected. This is especially true if there is an added inert gas in the system. The arsenic must diffuse from the cold sink, dissolve, and the melt must be mixed. Obviously the reverse distillation process also takes time. To adjust the stoichiometry, the growing crystal should be withdrawn and time should be allowed for the new equilibrium to be established.

The weight of arsenic in the vapor phase is not negligible; arsenic gas has four atoms per molecule. Even a laboratory puller may well hold about 1.5 gm of arsenic at 1 atm and a mean temperature of 700°C. If a 150 gm charge of GaAs is melted in this crystal puller, the loss in arsenic will throw the melt 1% off stoichiometry. For this reason it is common practice to add a few grams of excess arsenic to fill up the vapor space.

The arsenic should not be put in the crucible with the GaAs charge. When arsenic sublimes it usually leaves a black ash-like residue, which is presumably an impurity. The ash is neither volatile, nor does it dissolve in molten gallium arsenide. Instead, it forms a scum which lies on the surface of the melt and interferes with crystal growth. The scum will also form on an initially clean melt if at any point the arsenic is allowed to condense on and then resublime from the surface of the charge.

Fig. 16—Pulled gallium arsenide crystal showing fine twinning caused by a nonstoichiometric melt.

One more point should be mentioned in connection with the stoichiometry of the melt. If by accident the arsenic vapor pressure is raised above 1 atm so that the melt is arsenic rich, a hazard can develop as the charge is frozen. Sometimes (especially with the magnetic puller) it is not possible to pull all of the material in the crucible. When the charge is cooled after the run, it freezes from the outside, while the core is still liquid. The arsenic concentration in the liquid increases as the arsenic rich melt solidifies. From Table I it can be seen that the vapor pressure increases sharply with arsenic concentration. The solid charge with its liquid core becomes like a grenade and a violent explosion can occur. This type of explosion is much more destructive and dangerous than the explosions which result from an accidental buildup of arsenic pressure in the vapor phase. In practice it is the better part of valor to lower the cold sink temperature to at the most 400°C for about ½ hour before freezing the charge. Under this circumstance the melt is sure to be gallium rich and quite innocuous.

Conclusion

The Czochralski crystal pulling technique is the most widely used and reliable method of growing semiconductor single crystals. The technology described in this article is basic to the technique, but there are many variants. The constant volume technique[15] allows crystals of uniform impurity concentration to be grown. The pedestal technique[16] is a hybrid of the Czochralski and the floating zone methods which eliminates the necessity of a crucible. The rate growing technique[17] allows the transistor structure to be built in during the pulling process. There

are also other techniques which are used in industry. High purity silicon crystals are prepared by the floating zone process.[18] Growth from a seed[8] in a horizontal boat is another preferred technique.

Recently attention has been directed in the research laboratory to the growth of dendritic crystals.[19] The dendritic growth is so radical that a completely new technology must be developed. Considerable effort is being devoted towards the evaluation of dendrites for device application. Finally a technique has been developed for the growth of silicon crystals by epitaxy[20] from the vapor phase.

These recent developments are quite exciting, and they will doubtless find their place in the industry. It will be a long time, however, before the pulling technique is abandoned, and it is the author's hope that this article has given some feeling for the nature of this valuable process.

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A Contactless Method For Measuring Resistivity Of Silicon

PAUL J. OLSHEFSKI*

A method for measuring resistivity of zone refined single crystals has been developed using radio frequency currents and fixed capacitive coupling. Resistivity is determined from an equivalent parallel conductance and its relationship with circuit Q. After an initial calibration, there are no involved equations to solve. Samples can be completely characterized with a minimum of time and effort.

In the processing of high purity silicon, it is often desirable to know the resistivity of the sample before or during subsequent zone refining. Conventional d.c. two- and four-point probe methods require sample preparation with the resultant introduction of unwanted contaminants. Several methods have been announced for the measurement of resistivity by contactless techniques. Henisch and Zucker[1] derived an empirical relationship between Q and resistivity using inductive coupling. Weingarten and Rothberg[2] described a direct determination of resistivity using capacitive coupling. W. Keller[3] published a similar technique. The method reported here utilizes 20 mcs radio frequency currents capacitively coupled from a sensitive Q-meter and eliminates

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the inconvenience of solving involved equations. It is a modification of the Weingarten-Rothberg approach.

Theory of Operation

The resistance of the silicon is expressed as part of a two-terminal RC series circuit. The series circuit is transformed into an equivalent parallel network, which in turn is added to a network representing a commercial Q-meter. The resistance of the silicon is now derived from the changes in circuit Q resulting from the added equivalent parallel conductance.

If a silicon crystal is placed in a polyethylene bag and two metal strips are wrapped around it, electrically the circuit equivalent consists of a series RC circuit. See Fig. 1.

This is readily transformed into an equivalent parallel network. Previous investigators[2] solved for the desired series resistance from the changes in the circuit parameters as a result of increasing the spacing between the coupling capacitors in 1 cm increments. The changes were measured using a Q-meter. The equation derived is

$$R = \frac{C_T\ \Delta Q}{\omega\ (C_1 - C_2)^2\ Q_1 Q_2} \qquad (1)$$

where

C_T = initial Q-meter capacitance at resonance
ω = $2\pi \times$ frequency
C_1 = Q-meter capacitance after the addition of the cable and coupling plates
C_2 = Q-meter capacitance with a silicon crystal inserted in the coupling plates
Q_1 = the indicated circuit Q with the plates spaced at 1 cm
Q_2 = the indicated circuit Q with the plates spaced at 2 cm
$\Delta Q = Q_1 - Q_2$

The method to be outlined employs 2 cm wide coupling capacitors with a fixed 1 cm spacing.

In addition, a spring loading mechanism assures a uniform pressure around the sample. This maintains the value of the coupling capacitors between given limits. The actual measured values fall between 15 and 20 picofarads, depending on the diameter of the sample. In order to further reduce the variations in capacity, a 2.8 picofarad condenser is inserted in series with the coupling plates. The impedance of the series network is now composed of a constant capacitive reactance and the variable resistance represented by the sample. This is shown in Fig. 2.

Transforming the series circuit into an equivalent parallel circuit, Fig. 2B becomes Fig. 3.

The susceptance B_c is a constant and is dropped from further consideration. The conductance G is now equal to:

$$G = \frac{R\ \text{silicon}}{Z^2} \qquad (2)$$

where

$$Z^2 = R^2\ \text{silicon} \times X_{ct}^2 \qquad (3)$$

We have now obtained the resistance of the silicon in terms of its equivalent parallel conductance. The basic relationship of parallel networks:

$$Q_p = \frac{\omega C}{G} \qquad (4)$$

offers a means of determining the conductance from the circuit Q. A Boonton Model 260A Q-meter operating at 20 Mcs was chosen for the measurement. Initially, the Q-meter together with the mechanical support and the coupling plates for the crystal was tuned to resonance. Using Eq. 4 and the values of Q and C as read on the Q-meter, a conductance G_1 was calculated. This represents the total conductance of the network.

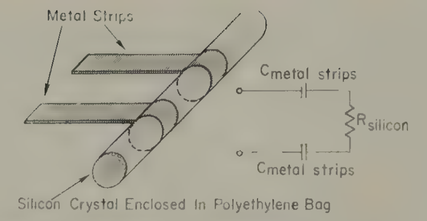

Fig. 1—Physical arrangement and its equivalent circuit.

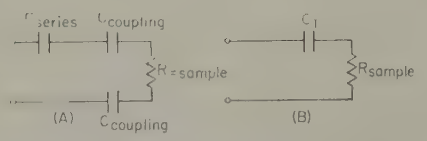

Fig. 2—Equivalent circuit with constant capacitive reactance.

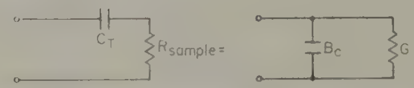

Fig. 3—Transformation of series circuit to equivalent parallel circuit.

With the addition of the silicon crystal, circuit Q is affected by the added conductance only, since the Q-meter sees no change in capacity. From Eq. 4 the new relationship becomes:

$$Q = \frac{\omega C}{G_1 + G_2} \qquad (5)$$

where

Q = indicated Q
ω = $2\pi \times$ frequency
C = capacitance as read on the Q-meter
G_1 = the total conductance of the Q-meter and network without a sample
G_2 = the added conductance due to the sample

Equation 5 is rewritten as:

$$G_2 = \frac{\omega C}{Q} - G_1 \qquad (6)$$

From Eq. 3 the equivalent series resistance of the silicon is expressed as:

$$R_{\text{silicon}} = \frac{Z^2\ \omega C}{Q} - Z^2 G_1 \qquad (7)$$

G_1, previously defined as the total conductance of the Q-meter and crystal support, is a constant; ω is a constant; Z^2 can also be considered as a constant (Eq. 3).

The reactance X_c of the small series condenser is about 2.8 K Ω and is constant. If the sample resistivity is 1000 ohm-cm, then the total resistance of 1 cm of sample length would be about 300 ohms. Therefore:

$$Z^2 \cong X_c^2$$

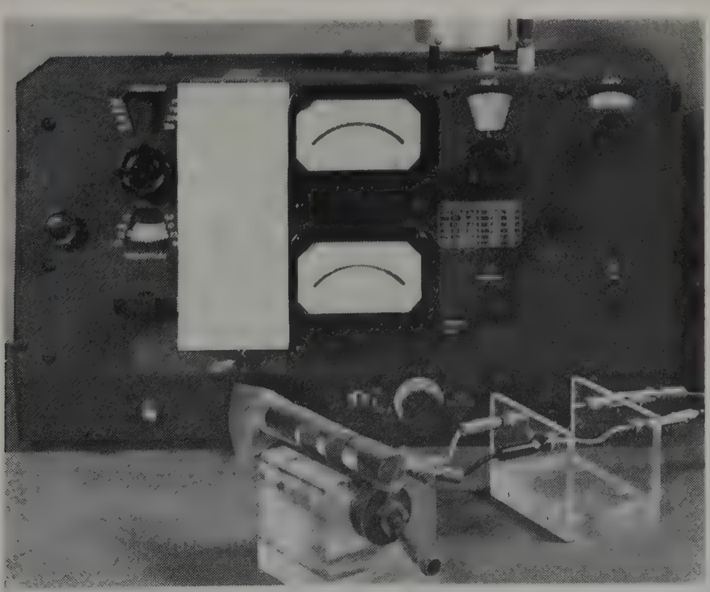

Fig. 4—Set up illustrating equipment for measuring resistivity.

If samples of the same diameter are held within allowable tolerances, then C becomes a constant. Equation 7 can now be rewritten as:

$$R_{\text{silicon}} = \frac{K_1}{Q} - K_2 \qquad (8)$$

Since the constants can readily be determined, a theoretical curve is obtained for resistance vs. Q (Fig. 5). More simply, a table of indicated Q values can be derived for the corresponding resistance values. If, as previously stated, the samples to be measured are held to close diameter tolerances, and the resistance values are multiplied by the appropriate cross-sectional area, a table of resistivity is obtained for corresponding Q-values (Table 1). Table 2 shows a comparison of resistivities determined by the Q-meter and by the d.c. two-point probe method. As is shown, very good agreement can be realized using this technique.

Variations And Limitations

The accuracy with which the Q-value can be read is a prime factor influencing the accuracy of the measurement. To circumvent the difficulty in reading a logarithmic Q-scale, the ΔQ scale is used. With the Q-meter and the coupling plates tuned to resonance, the ΔQ scale is set at zero. Any changes in circuit Q resulting from the addition of a crystal can be accurately determined. This technique is applicable in the lower resistivity ranges where the change in Q is below 50.

The resistivity range that can be measured by this method is controlled by several factors. Of prime importance is the energy distribution within the network. Due to the insertion of the series condenser, a small portion of the total energy is available to the sample under test. On low resistivity samples, the added conductance (Eq. 5) must change the total conductance of the network an appreciable amount to effect a significant change in circuit Q. The limit, therefore, is established by the internal conductance of the Q-meter. On high resistivity samples, the impedance of the series network can no longer be considered constant. In addition, the total energy dissipated becomes negligible and circuit Q is unaffected. Figure 5 shows the theoretical curve for R vs Q for the range of 50-150 ohm-cm with experimentally determined results. Above 35 ohms or 110 ohm-cm material, the measured values of Q begin a progressive departure from theory for reasons previously mentioned. This portion of the curve can still be used to determine resistivity. However, the relationship must be considered empirical.

Various other resistivity ranges can be achieved by changing circuit parameters. By using a higher Q coil, a balanced transmission line in place of coax, and a higher operating frequency, the resistivity range of 1-50 ohm-cm can be measured. These changes help reduce the total conductance of the network and to increase the amount of energy available to the sample.

An additional approximation must be mentioned. The high frequency currents are coupled through condenser plates spaced 1 cm apart. Therefore it is necessary to assume that the current distribution is more or less uniform through the sample. If this is the case, the portion of the sample being measured lies between the inside edges of the coupling capacitors. In light of the results, the approximations appear valid.

In obtaining the profile of a crystal, measurements should be avoided on the extreme ends of the sample. The high frequency carrier can generate various end effects that interfere with the measurement.

Table 1—Tabulated results obtained from the graph of Figure 5

Q Value	Resistivity (ohm-cm)	Q Value	Resistivity (ohm-cm)
130	30	120	96
129	33	119	105
128	38	118	113
127	43	117	122
126	54	116	133
125	58	115	143
124	61	114	155
123	68	113	170
122	76	112	182
121	85	111	190
		110	200

Conclusion

Utilization of this method permits the measurement of resistivity on uniformly packaged single crystals. After an initial calibration, no further equations are involved.

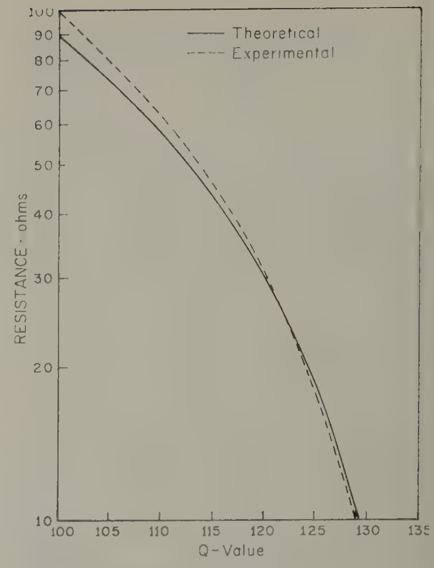

Fig. 5—Variation of Q with resistance.

The use of high frequency currents has a distinct advantage when measuring semiconductor materials having high resistivity surfaces. Since ohmic contacts are not required, this surface layer is effectively by-passed.

Acknowledgment

The author wishes to express his warm appreciation to Mr. J. Cwiklik for his assistance in accumulating the data and helping with the measurements, and to Mr. F. Bourassa for his helpful discussions.

Table 2—This comparison of data was obtained by calculating resistivity from the value of resistance as measured by the Q-meter

Crystal No.	D.C. two-pt. probe	Q-meter
1	214	220
2	200	190
3	180	185
4	155	154
5	105	107
6	95	88
7	73	75
8	58	60
9	45	47
10	33	34

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APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 76

Circle 198 on Reader Service Card

Introduction to the Shockley 4-Layer Diode; Shockley Transistor, Unit of Clevite Transistor, Palo Alto, Calif.

The Shockley 4-layer diode is a two terminal, silicon, semiconductor *switch*. It has two stable states as shown in the V-I Curve of Fig. 76.1. The "off" or high impedance state is shown in Region I, and the "on" or low impedance state is shown in Region III. To turn the device on, voltage across the terminals must exceed switching voltage (V_s). The 4-layer diode is turned off by reducing the current flowing through the device below holding current (I_h).

How the 4-Layer Diode Operates

The voltage-current characteristic for the 4-layer diode shows three essential operating regions:

I—"off" or high resistance state
II—transition or negative resistance state
III—"on" or low resistance state

This curve is shown on a very expanded scale (non-linear) for illustration purposes only. Note that as the voltage rises and reaches the switching voltage (V_s), the device begins to switch "on". The current at this point (I_s) is typically several microamperes. The device switches because of an internal feedback mechanism allowing the diode to pass a steadily increasing current as the voltage decreases (negative resistance state, Region II). When "on" (Region III), the 4-layer diode passes a current which is limited principally by the external circuit.

In the "on" state, the device has a dynamic resistance of less than a few ohms and a voltage drop of about one volt. As long as sufficient current is passed by the circuit, the device will remain in the "on" condition. At the point on the curve marked I_h, the circuit is passing just enough current to keep the device in the "on" condition. If the current drops below I_h, the diode switches back to the high resistance or "off" condition.

Devices are now available with switching voltages (V_s) from 20 to 200 volts and holding currents (I_h) from 1 to 50 ma. From this series of standard ranges it is possible to select diodes with the proper characteristics to meet specific circuit requirements.

Turning the device "On"

Before switching, one of the junctions of the 4-layer diode is reverse biased and acts as a capacitor. It is necessary to discharge this capacitor as well as inject current carriers into the device in the course of switching. This requires energy which must be furnished either by the trigger pulse or by circuit elements provided for this purpose. Within the circuit this energy is usually supplied by using a capacitor, the value of which is typically one hundred times the junction capacitance of the 4-layer diode being used. (*e.g.* For a twenty volt Type D diode this capacitor is normally .003 μf or greater). Under these conditions turn-on time is typically less than 0.1 μs. A series resistor should be included in the discharge circuit to limit the peak current passing though the device.

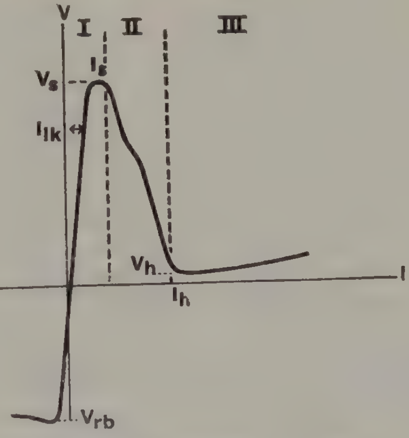

Fig. 76.1—Charateristic V-I curve.

Turning the device "Off"

The 4-layer diode turns "off" when the current though it is reduced below holding current. In the process of turning "off" the charge which was stored in the device during the "on" condition must be removed. In a typical sawtooth oscillator circuit, the turn-off time is determined by the rate at which charge naturally decays within the device. Turn-off time under these conditions is typically 0.5 to 1 μs, depending on circuit conditions.

Leakage Current and Capacitance

Leakage Current (I_{lk}) is measured with the Shockley 4-layer diode in the "off" condition. At 75% of the nominal switching voltage, leakage current is typically several microamperes.

In its "off" condition, the 4-layer diode may be characterized by a capacitance and large resistance in parallel. This capacitance is similar to the collector capacitance of a normal transistor. It has a value of 4 to 60 *pf* depending on the nominal switching voltage of the diode and the actual voltage across the device. In its "on" condition, the diode has such a low resistance that capacitive effects may be ignored.

Protection Against Reverse Breakover

In the reverse direction, 4-layer diode breakover resembles that of a voltage regulator or an avalanche (Zener) diode—*See Fig. 76.1* with the breakover voltage (V_{rb}) at least 50% of switching voltage (V_s). The power dissipation in the reverse direction is much greater than in the forward direction for the same current. It is easy, therefore, to damage devices if excessive current flows in the reverse direction and protection against this is strongly recommended.

APPLICATIONS ENGINEERING DIGEST NO. 77

Circle 199 on Reader Service Card

Silicon Field-Effect Transistors; Crystalonics, Inc., Cambridge, Mass.

Fig. 77.1 shows a schematic representation of a field-effect transistor. The unit consists of an n-type silicon bar with two ohmic contacts, cathode and anode, on either end of the bar. Two p-n junctions are built into the middle of the bar, and connected in parallel to serve as the grid of the device.

A negative bias applied to the grid projects a depletion layer, shown in broken lines, from each junction into the silicon. This increases the effective resistance between the anode and cathode of the unit, and gives rise to a triode type output characteristic. As the anode voltage is increased, the grid junctions are reverse biased by the voltage drop occurring due to the anode current. This reverse bias also causes a depletion layer to extend into the channel from each junction, with the two layers eventually meeting in the bulk of the silicon material. At that point, a further increase in anode voltage will not result in any appreciable increase in anode current, causing the output characteristics of the unit to closely resemble those of the thermionic pentode.

The anode potential, at which the saturation of anode current occurs, is known as the "Pinch-Off Voltage". The

anode current flowing through the device after the "Pinch-Off Voltage" has been reached is known as "Pinch-Off Current". With zero grid bias, the "Pinch-Off Current" is the maximum specified anode current of the transistor. The device is said to be in the triode region before the "pinch-off" occurs, and in the pentode region after the "pinch-off" potential has been reached. Typical output characteristics are shown in *Fig. 77.2*.

The field-effect transistors are inherently low noise devices. The noise level of these units when used with

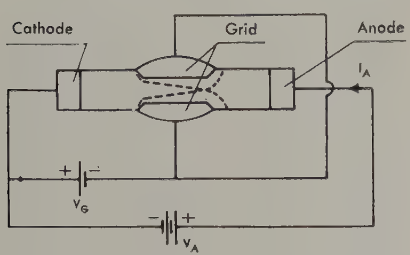

Fig. 77.1—Physical construction of the field-effect transistor.

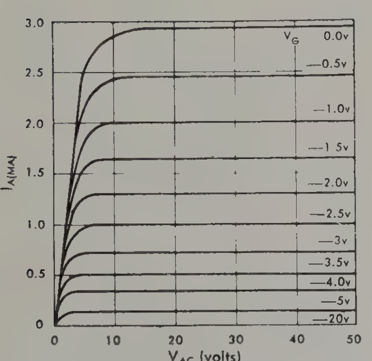

Fig. 77.2—Typical output characteristics.

high impedance sources is typically below those of the best low noise conventional transistors, and is largely independent of the source impedance. Field-effect transistors show extremely low noise values even with an open grid.

Fig. 77.3 shows the circuit symbol of the field-effect transistor. The anode and cathode terminals are, in general, interchangeable, although a somewhat higher transconductance and lower noise figure is generally obtained if the unit is used in the specified manner.

High Input Impedance Amplifiers

Circuitry for use of the field-effect transistors as amplifiers is identical with that of thermionic triodes and pentodes, except that lower anode voltages can be used for the field-effect devices. Polarities of applied voltages are also the same.

It should be noted that the field-effect transistor has useful transconductance over the entire specified temperature range of —55°C to +160°C, with the transconductance improving at the lower temperature. Care should be taken to allow for the increase in the grid current with temperature. A typical amplifier stage is shown in *Fig. 77.4*. Automatic biasing is recommended to reduce the variation of the anode current with temperature. This may be accomplished with a resistor in the cathode circuit. For closer control, a thermistor in connection with the cathode resistor, may be used.

Switching Circuits

Field-effect transistors can be used as switches in digital as well as analogue work *(Fig. 77.5)*. Unlike transistors, they require pulses of only one polarity for full "on"—"off" operation. The device is "on" when no voltage appears on the grid, and "off" condition, the resistance of the device is in the order of 100 Megohms. "On" resistance of the device is approximately 2K. Since the input capacitance of the device is approximately 50 pf, the switching speeds are directly affected by the impedance of the generator driving the switch. For high switching speed, the driving generator should be of low impedance both during the build-up and collapse of the driving pulse.

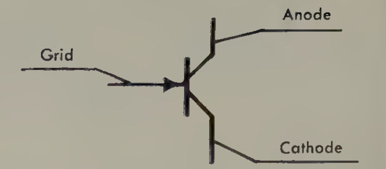

Fig. 77.3—Field-effect transistor symbol.

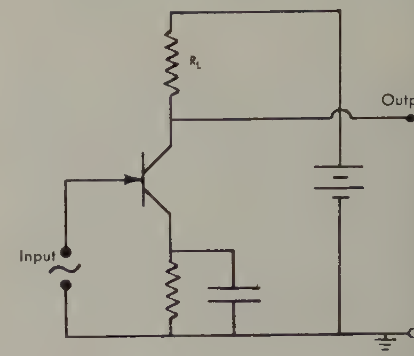

Fig. 77.4—High input impedance amplifier.

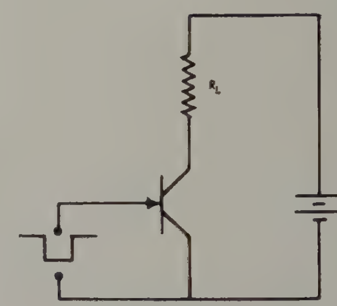

Fig. 77.5—Switching circuit.

APPLICATIONS ENGINEERING DIGEST NO. 78

Circle 200 on Reader Service Card

Common Emitter versus Common Base Operation; Motorola Inc., Semiconductor Products Div., Phoenix, Ariz. (W. A. Rheinfelder)

Among the considerations generally advanced in favor of the common-base configurations are (1) feedback capacitance, (2) impedance mismatch, and (3) current feedback. These characteristics, and the reasons why they do not pertain in like manner to the mesa transistor, are discussed below.

Feedback Capacitance

In common-base operation the feedback capacitance output to input will be lower than in common-emitter operation if an alloy transistor is used. This is because the relatively large base acts as a shield between collector and emitter beads, in a way analogous to grounded-grid operation in a vacuum tube. This condition does not exist in the mesa transistor. Here the collector forms the mesa and on it, side by side, are the small emitter and base stripes. Whichever is grounded has only a minor effect on the feedback capacitance; therefore common-base operation does not reduce the feedback capacitance in mesa transistors.

Impedance Mismatch

Common-base operation seems to provide added stability because of the greater impedance mismatch which is inherent in this circuit. The same impedance mismatch could be obtained in the common-emitter circuit but with a higher resultant power gain. Generally, matching is undesirable in high-frequency circuits.

As a rule of thumb, the maximum over-all power gain is achieved with a load of about one-fourth the parallel output resistance of the transistor. There would be a 2-*db* mismatch loss, but this is usually offset by increased network efficiency. Also, since the load is one-fourth, the voltage gain is also reduced by about the same factor, which means stability is four times higher—since stability is a function only of voltage gain, not power gain. Considering this, in the common-base circuit the output impedance is increased and the input impedance is decreased. This results in a much greater impedance mismatch with reduced power gain, reduced voltage gain, and in-

(Continued on page 59)

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PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Oct. 6, 1959 to Nov. 10, 1959. In subsequent issues, patents issued from Nov. 10, 1959 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

October 6, 1959

2,906,945 Apparatus for Effecting an Electric Control in Response to a Magnetic Field—H. Weiss. Assignee: Siemens-Schuckertwerte A. G. (Germany). Electrical control apparatus utilizing Hall-effect devices.

2,906,959 Electronic Organ—R. H. Peterson. Assignee: None. An individual oscillating circuit is used to produce any one of a plurality of adjacent semitones without using special external switching arrangements.

2,906,968 Transistor-Controlled Reactance Modulator—G. F. Montgomery. Assignee: USA (Department of Commerce). A diode reactance modulator employing a transistor control amplifier.

2,907,000 Double Base Diode Memory—J. D. Lawrence, Jr. Assignee: Sperry Rand Corp. A memory circuit employing double base diodes as memory cells permits non-destructive read out at high signal level.

2,907,642 Apparatus for Fusing Pulverulent Semiconductor Material—T. Rummel. Assignee: Siemens and Halske A. G. (Germany). Apparatus for fusing powdered semiconductor material into a melt by means of a gas or vapor stream which acts as a conveying medium for the powder.

2,907,895 Transistor Trigger Circuit—A. J. van Overbeek. Assignee: North American Philips Co. Inc. A switching circuit.

2,907,896 Pulse Generating Circuit—R. Yii. Assignee: Burroughs Corp. A transistor circuit in conjunction with a mechanical device results in a circuit interrupter in which the effect of contact bounce is greatly reduced and which produces a clean waveform having a rise time on the order of one microsecond.

2,907,897 Pressure Transducer—H. H. Sander. Assignee: USA. (U.S. Atomic Energy Commission). A device which utilizes the effects of a pressure controlled magnetic field on the conducting properties of a transistor.

2,907,898 Transistor Shift Register—E. G. Clark. Assignee: Burroughs Corp. A computer component.

2,907,899 Deflection Circuit—L. J. Kabell, E. D. Jones. Assignee: A. B. Dick Co. In a cathode ray oscilloscope, means for producing stable beam deflection voltages in response to digital input signals.

2,907,931 Control Apparatus—W. Moore, Jr. Assignee: Minneapolis-Honeywell Regulator Co. A vane controller including a transistor oscillator circuit as the movable vane position sensing means.

2,907,932 Phase Discriminating Apparatus—T. A. Patchell. Assignee: Minneapolis-Honeywell Regulator Co. A temperature stabilized phase discriminating control device including junction transistors for operating relays.

2,907,934 Non-Linear Resistance Device—J. M. Engel. Assignee: General Electric Co. A single junction device which can be used as an amplifier, a switching component, or a photoconductive element.

2,907,935 Junction-Type Semiconductor Device—H. Nagorsen. Assignee: Siemens-Schuckertwerte A.G. (Germany). A semiconducting device and a heat dissipating structure therefor.

2,907,954 Transistor Test Set—A. J. Radcliffe, Jr. Assignee: International Telephone and Telegraph Co. A test set which determines the grounded base current gain, grounded emitter current gain, base resistance, emitter resistance, collector resistance, and effective series resistance of a transistor device.

2,907,969 Photoelectric Device—R. G. Seidensticker. Assignee: Westinghouse Electric Corp. A semiconductor photocell which simultaneously functions as a photosensitive device and a high gain amplifier.

October 13, 1959

2,908,762 Party Line Identification System—L. A. Meacham. Assignee: Bell Telephone Labs. In a telephone subset, a transistorized ringer amplifier is selectively tuned to a frequency different from that of the other party line subsets and said amplifier is made to oscillate briefly at the characteristic frequency when a call is initiated, thereby facilitating identification of the calling subset.

2,908,828 Transistor Binary Adlers—E. C. Thompson. Assignee: Bell Telephone Labs. A binary adder which also performs pulse amplifying and limited pulse standardizing functions.

2,908,829 Control System with Stepped Output Transistor Amplifier—D. K. Schaeve. Assignee: Barber-Colman Company. Means for sharply changing the output level of a transistor amplifier in response to slow variations in the amplitude of the input signal.

2,908,830 Electronic Computing Circuits Utilizing Enchancement Amplifiers—H. L. Mason, D. L. Noble. Assignee: Sperry Rand Corp. Arithmetic and logical computer circuits using high frequency semiconductor diodes which utilize the effect of large inverse voltage induced reverse transient current.

2,908,851 Voltage Sensitive Semiconductor Capacitor—M. F. Millea, J. B. Holland. A silicon voltage sensitive crystal capacitor.

2,908,860 Testing Apparatus—R. J. Kircher. Assignee: Bell Telephone Labs. A transistor oscillator is employed in apparatus for testing switchboards and other contact making equipment.

2,908,871 Negative Resistance Semiconductive Apparatus—K. G. McKay. Assignee: A wide frequency band, two-terminal oscillator, employing a negative resistance semiconductor device.

October 20, 1959

2,909,411 Production of Silicon—I. J. Krchma. Assignee: E. I. duPont de Nemours & Co. In the process for producing silicon by vapor phase reduction of silicon tetrachloride with high purity zinc or cadmium, means for increasing the purity of the reductants.

2,909,453 Process for Producing Semiconductor Devices—E. F. Losco, G. Strull. Assignee: Westinghouse Electric Corp. A phototransistor device including a planar transparent evaporated emitter junction and a fused collector junction associated therewith.

2,909,672 Electric Governor for Prime Movers—F. P. Emery. Assignee: Westinghouse Electric Corp. Apparatus for sensing changes in the load connected to a generator and for governing the response of the generator's prime mover in order to maintain a constant frequency output.

2,909,674 High Frequency Relay—J. K. Moore, S. Schneider. Assignee: Burroughs Corp. A transistor circuit which functions as a switch or relay and which is operable at frequencies in excess of 0.5 megacycles.

2,909,675 Bistable Frequency Divider—J. O.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

Edson. Assignee: Bell Telephone Labs. A symmetrical bistable transistor multivibrator is used to divide the frequency of a driving voltage in such a manner as to produce an integral submultiple frequency.

2,909,676 Transistor Comparator Circuits for Analog to Digital Code Conversion—L. C. Thomas. Assignee: Bell Telephone Labs. Means for converting analog voltage levels into digital pulses.

2,909,677 Transistor Current Limiter—Q. W. Simkins. Assignee: Bell Telephone Labs. A current pulse limiter for driving nonlinear loads.

2,909,678 Transistor Control Circuits—A. K. Jensen. Assignee: Bell Telephone Labs. Transistor control arrangements for bistable direct-coupled transistor logic circuits.

2,909,679 Hall Effect Circuit Employing a Steady State of Charge Carriers—G. Abraham. Assignee: None. An arrangement in which a single magnetic field may be used to control a plurality of nonlinear devices which are employed in a circuit having more than one stable state.

2,909,680 Conditional Steering Gate for a Complementing Flip Flop—J. K. Moore, S. Schneider. Assignee: Burroughs Corp. Steering means which inhibits reversal of the flip-flop until the input pulse is completed.

2,909,705 Control Circuit—C. Husson. Assignee: Westinghouse Electric Corp. A control circuit, including a hyperconductive transistor switch, for firing an electrical discharge tube.

2,909,715 Base Contacts for Transistors—W. A. Adcock. Assignee: Texas Instruments Inc. In a method of making connections to the base of a grown junction transistor, means for avoiding direct contact of the base lead material with the emitter region.

2,909,717 Semi-Conductor Arrangement—H. Veith. Assignee: Siemens & Halske A. G. (Germany). A semiconductor rectifier made of an alkaline earth titanate having a dielectric constant greater than 100.

2,909,720 Current Supply Apparatus—E. Fthenakis. Assignee: Bell Telephone Labs. A transistor amplifier controlled magnetic amplifier for regulating current supply to a load in accordance with variations of load voltage.

2,909,730 Transistor Gain-Bandwidth Test Circuit—W. C. Timm. Assignee: Bell Telephone Labs. Test apparatus for determining the inverse gain bandwith of a transistor.

2,909,732 Device for Maintaining Mechanical Oscillations—A. J. Van Overbeek. Assignee: North American Philips Co. Inc. A small electromechanical oscillating system and means for maintaining the oscillations therein.

October 27, 1959

2,910,346 Recovery of Germanium Values—T. J. Manns. Assignee: Philco Corp. A process for recovering germanium from etchants containing hydrofluoric acid and an oxidizing agent which have been used on germanium surfaces during transistor manufacture.

2,910,394 Production of Semi-Conductor Material for Rectifiers—T. R. Scott, G. King, J. M. Wilson. Assignee: International Standard Electric Corp. A process for producing semiconductor material by decomposition of a gaseous silicon or germanium hydride under controlled conditions of temperature and pressure.

2,910,594 Magnetic Core Building Block—E. W. Bauer, M. K. Haynes. Assignee: International Business Machines Corp. A saturable magnetic core switching element which produces both true and complement output signals.

2,910,596 Non-Saturating Transistor Ring Counter—A. W. Carlson. Assignee: USA (Department of the Air Force). A ring counter in which only one stage may be in the *on* state at any one time, and in which the *on* transistor is not saturated in order to eliminate hole storage effects associated with the saturated state.

2,910,597 Switching Apparatus—T. M. Strong. Assignee: International Business Machines Corp. A circuit arrangement which provides bipolar clamping action to a signal line.

2,910,602 Light Sensitive Devices—H. G. Lubszynski, E. F. McGill, S. Taylor. Assignee: Electric and Musical Industries Ltd. (England). An antimony selenide light sensitive device including a layer of sponge antimony selenide, said device having increased sensitivity at the red end of the visible spectrum.

2,910,634 Semiconductor Device—R. F. Rutz. Assignee: International Business Machines Corp. A multielectrode configuration for a transistor device.

2,910,637 Control Devices Having a Phase Discriminator—G. Garnier. Assignee: Air-Equipment (France). A transistor voltage control device for use with motors which have a phase sensitive direction of rotation.

2,910,653 Junction Transistors and Circuits Therefore—R. L. Pritchard. Assignee: General Electric Co. An audio frequency negative resistance junction transistor oscillator circuit.

2,910,670 Electrical Circuits—R. M. Wolfe. Assignee: Bell Telephone Labs. A shift register and gating circuit which will provide output circuits of any desired shape, voltage, and polarity.

2,910,688 Electronic Horn—W. A. Kelley, R. D. Mohler. Assignee: Motorola, Inc. An automotive horn including a low current drain transistor oscillator, which is coupled to a loud speaker, said horn being capable of generating a plurality of tones.

2,910,689 Transistor Horn—B. J. Grace. Assignee: Motorola, Inc. An electronic automotive horn, including means for automatically controlling the volume thereof in accordance with the speed of the vehicle.

November 3, 1959

2,911,474 Telephone Alarm System—S. B. Weinberg, O. H. Williford. Assignee: Bell Telephone Labs. An active fire and burglar alarm system which operates in conjunction with telephone equipment and includes means for providing a signaling frequency outside the range normally used by telephone equipment.

2,911,475 Electrical Signalling Systems—F. H. Bray, R. G. Knight. Assignee: International Standard Electric Corp. A signalling system for use in an automatic telephone exchange system.

2,911,479 Control of Selecting Magnets in Cross-Bar Switches—C. G. Svala, K. G. Brunberg. Assignee: Telefonaktiebolaget L. M. Ericsson (Sweden). A transformer circuit including a transistor indicator for achieving the above mentioned objective.

2,911,545 Semiconductor Apparatus—B. H. Pinckaers. Assignee: Minneapolis-Honeywell Regulator Co. A transistor phase selective condition control circuit.

2,911,562 Television Camera Circuits—G. H. Fathauer. Assignee: Thompson Ramo Wooldridge Inc. In a television camera circuit, means for automatically varying the signal electrode current to obtain optimum performance under all conditions of illumination.

2,911,566 Deflection System for Cathode Ray Tubes—D. R. Taylor, Jr., P. Z. Ingerman. Assignee: Philco Corp. In a transistorized deflection system, nonlinearities in the deflection signal are compensated for by means of the action of frequency responsive network and a degenerative feedback circuit.

2,911,594 Transistor Measuring Method and Apparatus—G. Knight Jr., D. E. Humez, R. A. Johnson. Assignee: United Aircraft Corp. Apparatus for measuring nine small signal parameters of point contact and junction transistors.

2,911,629 Magnetic Storage Systems—H. J. Wetzstein, Z. K. Kawecki. Assignee: RCA. A magnetic core analog storage system possessing an indefinitely long period of storage for information contained therein.

November 10, 1959

2,911,773 Method of Cutting Semiconductive Material—A. R. Gobat. Assignee: International Telephone and Telegraph Corp. A technique for cutting small units of semiconductor material out of a block thereof by making shallow sequential sets of mutually perpendicular cuts in the face of said block.

2,912,311 Apparatus for Production of High Purity Elemental Silicon—R. W. Mason, A. W. Yodis. Assignee: Allied Chemical Corp. High purity silicon is produced by vapor phase reaction of a silicon tetrahalide and a vaporized reducing metal.

2,912,354 Moisture-Proofed Semiconductor Element—G. Jung. Assignee: Siemens and Halske A.G. (Germany). A moisture-proof coating for a semiconductor element.

2,912,502 Waystation Employing Transistor Amplifier—H. C. Talcott. Assignee: General Telephone Laboratories, Inc. In a telephone system in which large number of stations are bridged across a common line, each station is provided with a high input-impedance, negative-feedback, transistor amplifier to reduce the bridging loss imposed on the line by the station.

2,912,572 Automatic-Gain-Control System Utilizing Constant Current Source—C. R. Wilhelmesen. Assignee: Hazeltine Research, Inc. A transistorized automatic gain control circuit for a radio receiver.

(To Be Continued)

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TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
A Study of the Quantum Efficiency of X-Ray Radiation Absorbed in a P-N Junction	Acta Poly Scandica Ph 13 302/1961	The quantum efficiency of the photoelectric effect was determined by measuring the short-circuit current delivered by a specially designed germanium diode when its carriers were excited with X-rays.	T. Stubb R. Greaffe
The Measurement of the Hall Effect With the Aid of Microwave Specimens Changing from N-Type to P-Type with Changing Temperature	Acta Poly Scandica Ph 11 294/1961	Measuring procedure and measurements; fitting of contacts and etching; the Hall constant; discussion and acknowledgement.	T. Stubb
Microminiaturization Work at the Royal Radar Establishment	Br Comm & Elecncs June 1961	Some of the practical problems and methods involved; also progress made in this field.	G. W. A. Dummer
Electrical Characteristics of Diffused InAs P-N Junction	Br JL Appl Phys June 1961	A study has been made at 300°K, 196°K and 77°K. Junctions used in this study were prepared by diffusing Cd into n-type InAs.	G. Lucovsky
A Proportional Transistor Switch	Control Engg June 1961	Pertinent design equations, plus a typical application circuit for using the proportional switch to control motor speed or a heater type load.	A. N. DeSautels
A Transistorized Schmitt Trigger	Elecl Design News June 1961	An expression for the upper trip point is derived. Circuit is analyzed. Circuit parameter effects discussed.	J. Corsiglia
Design Simple, Phase-Stable Limiters	Elecnc Design June 7 1961	Discussion of design of shunt diode limiter, series diode limiter, series bridge limiter, and cascade amplifier.	I. Dlugatch
The Transistor as A Temperature Sensing Device	Elecnc Engg. (Br) June 1961	The method of using a transistor, in the CB circuit, for the detection of temperature changes in a temperature controlled system is examined in some detail.	J. E. Pallett
A Quick Method for Calculating Transistor Amplifier Circuits	Elecnc Engg. (Br) June 1961	If the hybrid parameter h_{12} is neglected, the transistor can be treated as a current amplifier, in a way analogous to a vacuum tube as a voltgae amplifier. Noise formulae are derived.	R. R. Vierhout A. J. H. Vendrik
Control Pulse Generation For a Digital Differential Analyser	Elecnc Engg June 1961	First of a series of four articles on the design and circuit details of a transistorized digital differential analyzer.	P. L. Owen M. F. Partridge T. R. H. Sizer
Evaluation of *AB* in Feedback Systems	Elecnc Equip Engg June 1961	Feedback design principles for vacuum-type amplifiers are developed and used for transistor amplifiers with external feedback added.	V. Uzunoglu
Doublers and Triplers Using Mesa Transistors	Elecnc Equip Engg June 1961	Graphical data that will aid in the design of frequency doublers and tripler stages required in transmitters.	W. A. Rheinfelder
Shunt D.C. Regulator Nomographs	Elecnc Industries June 1961	Step-by-step procedure, complete with equations and nomographs.	T. W. Kirchmaier
Rise Time for Medium Power Transistors	Elecnc Industries June 1961	A step-by-step example is worked out point-by-point with a nomograph.	K. P. Kuffer
Design Nor Circuits for Maximum Reliability	Electronics June 2 1961	A step-by-step design of a fundamental transistor circuit is detailed, showing methods of designing for maximum reliability under worst-case conditions.	K. M. Trampel
Transistor Cascade Circuit Improves Automatic Gain Control in Amplifiers	Electronics June 2 1961	An improved method of applying a-g-c to transistor i-f amplifiers.	J. F. Perkins, Jr.
Microwave Isolator Combines Hall Effect and Tunnel Diodes	Electronics June 16 1961	A three-terminal Hall plate is used in this configuration.	C. H. Hubbard L. A. LoSasso E. Rousso
Equations and Procedure For Designing Transistor of Zener Shunt Regulators	Electronics June 30 1961	Circuit diagram as basis of equation derivation is used in this analysis.	M. Beebe
Four-Layer Diode Triggers High-Voltage Pulse Generator	Electronics June 30 1961	Simple generator uses four-layer diode to discharge a capacitor. Lockout circuit prevents diode from remaining in the conducting state, allows 1-KV output at 10,000 pulses per second.	N. C. Hekimain P. M. Schmitz
Photoelectric Cells and Multipliers 1: Vacuum Photoelectric Cells	Elecnc Technology June 1961	Survey presents, in simple terms, a discussion of the properties and applications of photoelectric cells and multiplier phototubes.	J. Sharpe
Semiconductor Rectifier Characteristics	Electro-Tech June 1961	Definitions of terms and description of forward and reverse characteristics. Design of circuits to be used in testing cells, including load tests.	E. J. Diebold
A Survey of Semiconductor Materials Technology	IRE Tr Comp Parts June 1961	The various processes for the preparation and growth of crystals are described, and an outline of their relative merits is given.	J. H. Myer
Esaki Diode NOT-OR Logic Circuits	IRE Tr Elecnc Comp June 1961	A basic technique is presented which enables the development of Esaki diode NOT-OR logic circuits.	H. S. Yourke S. A. Butler W. G. Strohm
Logic Circuits Using Square-Loop Magnetic Devices: A Survey	IRE Tr Elecnc Comp June 1961	A capsule view of twenty-four square-loop magnetic logic circuits which have been proposed or developed so far.	J. L. Haynes
High-Speed Analog-To-Digital Converters Utilizing Tunnel Diodes	IRE Tr Elecnc Comp June 1961	Two analog-to-digital sequential converters have been devised which combine in one tunnel-diode pair per bit the functions of an amplitude discriminator and memory.	R. A. Kaenel
An Accurate Analog Multiplier and Divider	IRE Tr Elecnc Comp June 1961	More precise switches can be designed with transistors than with tubes, and the zero drift in the time-division multiplier can thus be improved considerably.	E. Kettel W. Schneider
The Zeiss Electron Microscope C in Metal Research	Jena Review No 4 1961	This article discusses some of the problems worked out at the Research Institute in Germany for special metal raw materials. Includes reference to etched patterns in solving problems of solid state physics.	H. Ringpfeil J. Edelmann

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Gallium Arsenide Esaki Diodes For High Frequency Applications	JL Appl Phys June 1961	The fabrication and characteristics of gallium arsenide Esaki diodes are discussed. The devices have been used in oscillators producing frequencies of up to 103 kMc.	C. A. Burrus
Imaginary Part of X-Ray Scattering Factor For Germanium. Comparison of Theory and Experiment	JL Appl Phys June 1961	A theoretical calculation of the imaginary part of the X-ray scattering factor for germanium yields values which are in close agreement with previously determined experimental results.	B. W. Batterman
Theory of Microplasma Instability In Silicon	JL Appl Phys June 1961	A statistical theory explaining microplasma instability at the onset of avalanche in reverse biased silicon junctions is presented. Experimental results give good confirmation of part of the theory.	R. J. McIntyre
Recombination Kinetics for Thermally Dissociated Li-B Pairs in Silicon	JL Appl Phys June 1961	The kinetics of a diffusion limited pairing reaction between oppositely charged impurity ions in a solid are studied. Measurements show that the kinetics are not of first order and that an appropriate model reveals little correlation between particular Li^+B^- ions.	E. M. Pell F. S. Ham
Oxygen Absorption on Silicon and Germanium	JL Appl Phys June 1961	Data concerning the sticking probabilities of oxygen on clean silicon and germanium are presented.	H. D. Hagstrum
Study of Li-O Interaction in Si by Ion Drift	JL Appl Phys June 1961	A study of the drift mobility of Li^+ ions in silicon samples containing oxygen reveals that at high concentrations the effective drift mobility is inversely proportional to the oxygen content.	E. M. Pell
Antimony Edge Dislocations in InSb	JL Appl Phys June 1961	Measurements on InSb crystals indicate that Sb dislocations tend to act as donors and In dislocations function as acceptors (letter to Editor).	H. C. Gatos M. C. Finn M. C. Lavine
Surface Potential of Silicon	JL Appl Phys June 1961	A method for measuring the surface potential of a semiconductor by means of the d-c field effect is described (letter to Editor).	C. T. Raymo G. W. Brands B. Schwartz
High Frequency Silicon Varactor Diodes	JL Appl Phys June 1961	Silicon varactor diodes have been fabricated which have a point contact configuration and have a zero-bias junction capacitance between 0.04 to 0.15 $\mu\mu$f (letter to Editor).	C. A. Burrus
Analytic Solution of Double Diffusion Problem	JL Appl Phys June 1961	Expressions are developed which describe the impurity concentration profile of the second diffusion in the double diffusion process of forming p-n junctions. (letter to Editor).	K. C. Nomura
Measurement of Minority Carrier Lifetime in SiC by a Novel Electroluminescent Method	JL Appl Phys June 1961	Minority carriers are injected from a sine wave source through a low rectification ratio injecting contact. A selected point on the curve of relative electroluminescent output versus the reciprocal of source frequency gives the value of the minority carrier lifetime (letter to Editor).	G. G. Harman R. L. Raybold
Germanium Films on Germanium Obtained by Thermal Evaporation in Vacuum	JL Appl Phys June 1961	Epitaxial growth in Ge films evaporated onto a Ge substrate have been observed when the epitaxial growth temperature was well below 800°C (letter to Editor).	O. Weinreich G. Dermit C. Tufts
Saturation Currents at N-Type Silicon and Germanium Electrodes in Chemical Etching Solutions	JL Electrochem Soc June 1961	Three practical applications are indicated: (a) a monitor for chemically etching semiconductors; (b) a tool to study the process of chemical etching; and (c) a simple method for fluoride ion analysis.	D. R. Turner
Gaseous Diffusion of Arsenic and Phosphorous Into Germanium	JL Electrochem Soc June 1961	The diffusion of arsenic and phosphorous from a gaseous ambient into germanium is investigated using capacitance and breakdown measurement of diodes produced by plating indium into indentations of various depths.	K. Lehovec C. Pihl
ZnS:Cu, Si Phosphors	JL Electrochem Soc June 1961	Firing of ZnS + $(CH_3COO)_2Cu$ + SiS_2 causes incorporation of copper and promotes orange fluorescence under firing conditions whereby the "selfcoactivated copper" emission is normally not obtained.	A. Wachtel
Growth Steps in Germanium Dendrites	JL Electrochem Soc June 1961	The two main faces of a number of germanium dendrites grown under different conditions have been examined in detail by optical, interference, and electron microscopy.	R. G. Booker
A Comparative Study of Infrared Luminescence and Some other Optical and Electrical Properties of ZnS:Cu Single Crystals	JL Electrochem Soc June 1961	An attempt has been made to fix the position of the optical transition leading to infrared luminescence of ZnS: Cu within the general picture of electronic states of crystal phosphors.	I. Broser H. J. Schulz
Vapor Phase Preparation of Gallium Phosphide Crystals	JL Electrochem Soc June 1961	A method is described for the preparation of single crystals of GaP by the vapor phase reaction of gallium suboxide with phosphorous.	M. Gershenzon R. M. Mikulyah
A Revised Theory of the Floating Crucible Technique of Crystal Growing	JL Elecncs & Con (Br) June 1961	The method of crystal growing analyzed by Airapetyants and Shmelev is re-examined. The present analysis takes account of one term omitted previously.	G. R. Blackwell
The Characteristics of Some Germanium Tunnel Diodes	JL Elecncs & Con (Br) June 1961	The procedures used to make tunnel diodes are described. By varying the alloying temperatures used, a controlled variation may be produced in the diode parameters. Their effects are discussed in terms of the tunnelling process.	B. Mroseiwicz E. Heesell
Infrared Absorption in Magnesium Silicide and Magnesium Germanide	JL Phys Chem Solids Vol 20 Nos 1/2	Infrared absorption spectra of several n-type single crystals were obtained in the wavelength region from 1-13 μ and 1-7 μ, over the temperature range from 83°-370°K.	P. Koenig D. W. Lynch G. C. Danielson
The Problem of Exciton Induced Photoemission from CdS	JL Phys Chem Solids Vol 20 Nos 1/2	It is shown that both the velocity and spectral distributions can be explained by the assumption of an exponential distribution of states from which the photoelectrons are directly excited by the photons.	W. E. Spicer
Thermal Conductivity of Silicon at Low Temperatures	JL Phys Chem Solids Vol 20 Nos 1/2	The thermal conductivity of several single crystal silicon samples have been measured over the range 2-200°K. Conductivities as high as 35 watts km deg. were observed.	J. C. Thompson B. A. Younglove
The Thermoelectric Power of Magnesium Cadmium Alloys	JL Phys Soc Jap June 1961	The thermoelectric power of magnesium cadmium alloys was measured relative to pure copper at temperatures between room temperature and 300°C.	S. Noguchi
Resonance Transfer of Ionization Energy in Semiconductors	JL Phys Soc Jap June 1961	The thermal conductivity caused by interelectronic interaction is calculated in each of three temperature ranges: extrinsic, exhaustion, and intrinsic.	S. Koshino T. Ando
Crystal Structures and Electrical Properties of Alkali Antimonides	JL Phys Soc Jap June 1961	Both X-ray study and electrical measurement were simultaneously carried out, keeping the specimen in a vacuum.	J. Chikawa S. Imanura K. Tanaka M. Shiojiri

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Two-Transistor Oscillator for Displacement Measurements	JL Sc Instmnts (Br) June 1961	For a frequency of 10 mc the daily drift of the oscillator alone may be as small as a few cycles per second.	L. M. Tremorisoux
Rapid Response Photomultipliers	Mullard Tech Comm June 1961	This article reviews some of the problems encountered in the design of photomultipliers with fast response.	G. Pietri
Transistor Multirange D. C. Millivoltmeter	Mullard Tech Comm June 1961	A portable d-c millivoltmeter having a maximum sensitivity of 10 mV full-scale deflection, and an input resistance of one million ohms per volt, is described.	K. Holford
Sampling Techniques Applied to High-Speed Pulse Oscillography	Mullard Tech Comm June 1961	The advantages of the closed-loop systems over the simpler type open-loop types are discussed. Semiconductor circuitry is employed.	B. Gilbert
The Junction Transistor Push-Pull Blocking Oscillator	Mullard Tech Comm June 1961	Operation of the oscillator is discussed. The expressions derived for the pulse lengths and the mark space ratio indicate the advantages of this type of oscillator over the single-transistor type.	B. Gilbert
The Influence of Non-Uniform Base Width on the Noise of Transistors	Philips Res Repts June 1961	It is shown that the discrepancy between the experimentally observed values of the noise resistance, Rn, and the values predicted by the noise theory of transistors is due to the presence of one or more regions with a non-uniform base width.	A. Baelde
Electron-Electron Scattering and Transport Phenomena in Nonpolar Semiconductors	Physical Review June 15 1961	The effect of electron-electron scattering processes due to Coulomb forces on the transport phenomena in nonpolar isotropic solids is treated in the framework of Kohler's variation principal.	J. Appel
Low-Frequency Conductivity Due to Hopping Processes in Silicon	Physical Review June 15 1961	The complex conductivity has been measured in n-type silicon with various kinds of impurities at frequencies between 10^2 and 10^5 cps, and temperatures between 1 and 20°K.	M. Pollack T. H. Geballe
Magnetoresistance of Oriented Gray Tin Single Crystals	Physical Review June 1 1961	The electronic band structure of gray tin was investigated through magnetoresistance measurements on oriented n- and p-type single crystals at 77°, 195° and 273°K.	O. N. Tufte A. W. Ewald
Effect of Temperature and Doping on the Reflectivity of Germanium in the Fundamental Absorption Region	Physical Review June 1 1961	The 2.1 and 4.4—ev peaks in the reflectivity spectrum of germanium have been studied as a function of temperature and doping.	M. Cardona H. S. Sommers, Jr.
High-Frequency Power in Tunnel Diodes	Proc IRE June 1961	An expression for the high-frequency tunnel-diode power is developed with a simple dissipative load and for signals confined within the nearly linear range of the diode negative resistance.	G. Dermut
Design Theory of Optimum Negative-Resistance Amplifiers	Proc IRE June 1961	In this paper general amplifiers obtained by imbedding a linear active 1-port device in arbitrary 3-port units are considered.	E. S. Kuh J. D. Patterson
The Optical Properties of Single Crystals of Cadmium Selenide	Proc Royal Soc (Br) Vol 262 No 1308 June 13 1961	Measurement of a number of the optical properties in which pure single crystals grown by sublimation in atmospheres of inert gas were used.	R. B. Parsons W. Wardzynski A. W. Yoffe
The Helix Parametric Amplifier, A Broadband Solid State Microwave Amplifier	RCA Review June 1961	Parametric amplifier uses a helix as a slow-wave distributed interaction structure and has variable-capacitance solid-state diodes distributively coupled to the helix.	C. L. Cuccia K. N. N. Chang
Thermoelectric Air Conditioner for Submarines	RCA Review June 1961	The basic design concept is discussed in terms of performance, pressurization, sea-water corrosion, and simplicity.	J. R. Andersen
A New Concept in Transistor Converters	Semiconductor Prods June 1961	This article describes the characteristics of a new double-emitter drift-field transistor, the 3746, and discusses its use in transistorized broadcast-band receivers.	L. Plus R. A. Santilli
Properties of Hall Effect Multipliers	Semiconductor Prods June 1961	The properties of Hall effect multipliers, such as geometry, terminal characteristics, power limitations, and temperature variation of output voltage are discussed.	S. P. Denker
Zener Diode Circuit for Stable Transistor Biasing (Part II)	Semiconductor Prods June 1961	In this installment the authors discuss a tolerance factor for transistor interchangeability, and experimental results obtained.	J. Kabell V. H. Grinich
Switching Time Formulae for Single Diffused Mesa Transistors	Semiconductor Prods June 1961	This article is intended to give the reader formulae necessary to calculate the four switching times: delay, rise, storage, and fall—from data sheets or easily measurable steady state quantities.	E. Severis
A New Method for Measuring the Volume Resistivity of Semiconductor Material	Semiconductor Prods June 1961	The four-point probe method now universally used for these measurements can be replaced with a microwave measurement at certain ranges of resistivity and slice thickness of material with an increase in accuracy and speed in measurement.	G. L. Allerton J. R. Seifert
Industry Reports—Materials and Machinery Used in the Semiconductor Industry	Semiconductor Prods June 1961	Existing status of suppliers of raw materials, production equipment, and machinery to the industry.	No Author
A New Dynamic Rating For the Emitter-Base Diode	Solid State JL June 1961	The emitter-base breakdown voltage may be exceeded on a transient basis in this rating.	J. A. Ekiss
Increasing the Q of a Filter Through the Use of Tunnel Diodes	Solid State JL June 1961	Summary of the results of experiments using tunnel diodes to raise the Q of a filter.	D. Sabih
Diffusion, Solubility, and the Effect of Silver Impurities On Electrical Properties of Silicon	Sov Phys Solid State May 1961	Fast diffusion rate and the presence of two deep levels allow diffusion alloying of silicon with silver when preparing uniform material with a given resistivity.	B. I. Boltaks H. Shih-yin
A Photoelectric Method of Observing Inhomogeneity with Depth in Semiconductors	Sov Phys Solid State May 1961	Observation of inhomogeneities in layers adjacent to the surface of a semiconductor are made by measuring the frequency dependence of the photoconductivity complex amplitude.	E. J. Rashba V. A. Romanov
A Method for Experimentally Testing the Possibility of Employing a Universal Surface Recombination Velocity When Investigating the Kinetics of Photoelectric Processes	Sov Phys Solid State May 1961	Consideration is given to the suitability of using the quantity complex universal surface recombination velocity $S(\omega)$, as a function of frequency to describe magnetic and optical effects in semiconductors.	E. I. Rashba
Distribution of Phosphorous Atoms During Diffusion in Silicon	Sov Phys Solid State May 1961	Direct studies are made of the variation of phosphorous concentration with depth by measurement of electrical resistance and Hall effect in samples from which very thin plane parallel layers have been removed by etching and grinding.	V. K. Subashiev A. P. Landsman A. A. Kukharskii

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
An Electrical-Diffusion Study of the Behavior of Indium and Antimony Impurities In Germanium	Sov Phys Solid State May 1961	The introduction and redistribution of impurities in germanium by means of electrical diffusion is discussed.	B. P. Konstantinov L. A. Badenko
Dependence of the Number of Radiation Defects in Silicon on the Initial Electron Energy	Sov Phys Solid State May 1961	A calculation is made of the total number of radiation defects in silicon as a function of the initial energy for a specific threshhold energy.	B. Y. Yurkov
Utilization of the Longitudinal and Transverse Magnetoconcentration Effects To Determine the Magnetoconductivity Coefficients in Anisotropic Crystals with Cubic Symmetry	Sov Phys Solid State May 1961	Matters in support of the use of the effects of the anisotropy of holes in germanium to investigate the magnetoconductivity coefficients therein are presented.	A. A. Grinberg S. R. Novikov
Capture and Recombination at Multielectron Capture Centers in Semiconductors	Sov Phys Solid State May 1961	Conditions under which capture occurs and the effect of capture on measurements of lifetime by different methods are considered.	S. G. Kalashnikov K. P. Tissen
Injection Phenomenon During Flow of Current Through a Nonhomogeneous Semiconductor	Sov Phys Solid State May 1961	A theory concerning minority carrier injection during current flow in semiconductors with uniform conductivity gradients is presented.	Z. A. Demidenko K. B. Tolpygo
Temperature Dependence of Basic Parameters of GaAs Point-Contact Diodes.	Sov Phys Solid State May 1961	A description of the method of preparation of point contact diodes on the base of n-type GaAs is given along with static current voltage characteristics over several temperature ranges and other device parameters.	D. N. Nasledov N. N. Smirnova B. R. Tsarenkov
Electrical Conductivity of Liquid Selenium in Strong Electric Fields	Sov Phys Solid State May 1961	Results of measurements of the electrical conductivity of liquid selenium in fields of up to 10^5 v./cm in a temperature range from 180°C to 350°C are presented.	A. A. Andreev A. R. Regel
The Mechanism of Electric Conductivity in Ferromagnetic and Antiferromagnetic Semiconductors	Sov Phys Solid State May 1961	A discussion on the relationship between electrical conductivity and magnetic ordering in these materials is given.	Y. M. Ksendzov
Oscillations of the Absorbtion Coefficient in Tellurium in a Magnetic Field Directed Along the Crystal Optic Axis	Sov Phys Solid State May 1961	The infrared absorption spectrum in Te single crystals is calculated. The calculation is carried out in the one electron approximation by the effective mass method.	L. I. Korovin T. Y. Bulashevich
Investigation of Trapping at Copper Atoms in Germanium	Sov Phys Solid State May 1961	Trapping in copper-doped n-type germanium was studied. It was found that trapping was principally caused by triply charged copper ions.	S. G. Kalashnikov A. I. Morozov
The Chemical Potential and the Criterion for Degeneracy of Conductivity Electrons in a Strong Magnetic Field	Sov Phys Solid State May 1961	The chemical potential in the quantum limit is considered for the degenerate, nondegenerate, and intermediate cases, with electron spin being taken into account.	A. I. Ansel'm B. M. Askerov
Effect of the Anisotropy of Crystals on the Thermal Vibration of Atoms in Ge and Si	Sov Phys Solid State May 1961	A study is made of the anisotropy of the phonon spectrum in Ge and Si.	A. G. Samoilovich V. D. Iskra
Electric Properties of Semiconducting In_2Te_3 with Defective Structure	Sov Phys Solid State May 1961	The electrical conductivity, thermoelectric power, Hall effect, carrier mobility, and chemical bonding characteristics of In_2Te_3 are investigated.	V. P. Zhuze V. M. Sergeeva A. I. Shelykih
The Polymorphism of In_2Te_3	Sov Phys Solid State May 1961	X-Ray analysis is used to investigate the structural transformation between α-In_2Te_3 and β-In_2Te_3. β-In_2Te_3 has a ZnS structure while α-In_2Te_3 has an FCC structure.	
Optical and Photoelectric Properties of In_2Te_3	Sov Phys Solid State May 1961	The absorption spectra and photoconductivity response of α and β-In_2Te_3 are investigated.	V. A. Petrusevich V. M. Sergeeva
Thermal Conductivity of Alpha and Beta Modifications of In_2Te_3	Sov Phys Solid State May 1961	The very low thermal conductivity of β-In_2Te_3 is attributed to scattering of phonons on randomly distributed vacancies in the indium sublattice, and is found to be independent of temperature.	A. I. Zaslavskii V. M. Sergeeva I. A. Smirnov
The Relation Between Thermal and Optical Properties of In_2Te_3	Sov Phys Solid State May 1961	A supplementary thermal conductivity in course-grained samples of In_2Te_3 at high temperatures is attributed to heat transfer by electromagnetic radiation.	V. A. Petrusevich V. M. Sergeeva I. A. Smirnov
Magnetoelectric Properties of Tellurium II. The Effect of Annealing on the Temperature Dependence of the Carrier Mobility	Sov Phys Solid State May 1961	Effects associated with annealing are observed to increase with increasing sample purity.	R. V. Parfen'ev I. I. Farbshtein S. S. Shalyt
Various Steady State Methods For Measuring the Thermal Conductivity of Semiconductors	Sov Phys Solid State May 1961	Difficulties associated with various techniques for measurement of the thermal conductivity of semiconductors are discussed and improved methods are suggested.	A. F. Chudnovskii
An Investigation of the Long Wavelength Fundamental Absorbtion Edge of CdS and ZnSe Polycrystalline Layers at Low Temperatures.	Sov Phys Solid State May 1961	The appearance of line structure in the absorption spectrum of CdS and ZnSe layers deposited on a substrate depends upon crystallite size within the layer.	E. F. Gross B. S. Razbirin V. I. Safarov
Study of the Decomposition of a Supersaturated Solid Solution of Copper in Germanium	Sov Phys Solid State May 1961	Data are presented on the structural changes which take place during the decomposition of supersaturated solution of copper in germanium.	A. M. Elistratov P. R. Kamadzhiev
Impact Ionization and Tunnel Effect in Semiconductors	Sov Phys Solid State May 1961	A discussion of the theory underlying the impact ionization and tunnel effects in p-n junctions.	B. M. Vul
Investigation of the Influence of Oriented Deformations Upon the Spectrum of the Basic Absorbtion Edge of Single Cu_2O Crystals.	Sov Phys Solid State May 1961	Deformation of single Cu_2O crystals due to uniaxial compression results in anisotropic polarized splitting of the long wavelength edge and of the exciton structure of the Cu_2O absorption spectrum.	E. F. Gross A. F. Kaplyanskii
The Effect of Adsorbed Oxygen On The Photo—EMF of Lead Sulphide Layers	Sov Phys Solid State June 1961	Adsorbed air was observed to have a reversible effect on the magnitude of the photo-emf in the temperature range 20°C to 200°C.	R. Y. BerLaga T. T. Bykova
Symmetry of Energy Bands in TlSe Type Crystals	Sov Phys Solid State June 1961	A study of the crystallographic properties of materials possessing a chain structure.	F. M. Gashimzade
Optical Properties and Photoelectron Emission of Amorphous and Crystalline Germanium Films	Sov Phys Solid State June 1961	Optical constants for thin amorphous and crystalline germanium films are calculated from data presented. The effects of varying the film preparation techniques are noted.	P. G. Borzyak R. D. Fedorovich
Electrical Conductivity of Germanium with Lithium Impurity at Low Temperatures	Sov Phys Solid State June 1961	Measurements were made at liquid helium temperatures of the specific resistance, the Hall coefficient, and the resistance variation in a magnetic field of Ge having a lithium impurity concentration.	I. A. Kurova N. D. Tyapkina
Specifying Collector Leakage Current in Constant V_c Circuit	Sperry Engg Rev June 1961	This paper is concerned with the predication of the collector leakage current rating that must be specified to assure safe operation under given conditions.	C. J. Michaels

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Thermoelectric Properties of $Bi_2Te_3—Bi_2Se_3$ Alloys	US Govt Res Repts May 1961 LC $1.80 PB 153753	The thermoelectric properties of the alloys are studied in the low temperature region.	R. T. Bate
Exponential Detectors	US Govt Res Repts May 1961 LC $4.80 PB 153736	The effect of the exponential diode characteristic on the output signal-to-noise ratio of circuits using diodes is studied.	C. Kaiteris
Modulation and Demodulation with Semiconductors	US Govt Res Repts May 1961 LC $9.30 PB 154843	A classification scheme for transistor modulation systems is given. System investigation indicates that transistors have no advantage over vacuum tubes with respect to linearity and distortion free operation.	D. P. Masher
Applications of Tunneling to Active Diodes	US Govt Res Repts May 1961 LC $10.00 PB 153873-2	The report discusses a reliability-failure property in GaAs tunnel diodes, a method for regrowing and doping GaAs from an alloy vapor state, and growth of intermetallic compounds by means of a halogen reaction in a closed quartz tube.	N. Holonyak Jr.
Basic Transport Phenomena in Germanium and Indium Antimonide	US Govt Res Repts May 1961 OTS $0.50 PB 171511	Studies of galvanomagnetic effects in semiconducting diamond in InSb; purification and single crystal growth are also discussed.	R. T. Bate S. E. Miller A. C. Beer
Influence of Magneto-conductivity Discontinuities of Galvanomagnetic Effects in InSb	US Govt Res Repts May 1961 LC $4.80 PB 153199	Anisotropic segregation of impurities during crystal growth causes patial discontinuities in carrier concentration with which anomalous galvanomagnetic effects have been observed in n-type InSb.	R. T. Bate J. C. Bell A. C. Beer
Applications of Tunneling to Active Diodes	US Govt Res Repts May 1961 LC $3.30 PB 153873-1	PbTe and PbS tunnel junctions have been prepared and studied, and low temperautre electrical measurements have been made thereon.	R. N. Hall
Theoretical and Experimental Works on Fast Diffusion Impurity Atoms In Semiconductors	US Govt Res Repts May 1961 LC $3.30 PB 153819	Summary of work and publications.	E. M. Pell
Transmission Line Formulation for Semiconductors	US Govt Res Repts May 1961 LC $13.80 PB 153932	A mathematical model for crystal band structures is presented.	P. Parzen
A Survey of Basic Research in Thermoelectricity	US Govt Res Repts May 1961 LC $3.30 PB 154770	The present status of research is surveyed.	W. W. Scanlon
A Theoretical Study of The Simultaneous Diffusion of Two Impurities Into Silicon Through An Oxide Layer, and The Diffusion of Boron Into Silicon Through Dioxide For 0.001 percent Source Strength	US Govt Res Repts May 1961 LC $4.80 PB 153603	No abstract.	M. O. Thurston J. Tsai K. D. Kang
A Transistorized Pulse Height Analyzer for Gamma Spectroscopy	US Govt Res Repts May 1961 LC $4.80 HASL-59	An AEC report.	R. T. Graveson
Radiation Tolerance of a Select Group of Semiconductor Diodes	US Govt Res Repts May 1961 OTS $0.50 SCTM-404-60-14	No abstract.	C. I. Westmark
Research and Development on Semiconductor Parametric Amplifiers	US Govt Res Repts May 1961 LC $15.30 PB 153268	The use of parametric and tunnel diodes in microwave amplifiers is investigated. A helix type amplifier employing 18 parametric diodes achieved a 200 MC bandwidth.	K. K. Chang H. J. Prager
Safe Thermal Operation of Power Transistors Under Pulsed Excitation	US Govt Res Repts May 1961 LC $12.30 SCDC-910	An AEC report.	G. R. Swain W. W. Grannemann
High Temperature Improved Efficiency Photovoltaic Solar Energy Converter	US Govt Res Repts June 16 1961 LC $6.30 PB 154525	Improved GaAs cells are discussed. Units 0.25 cm² in area have been fabricated which demonstrate an overall conversion efficiency of 5 per cent.	J. J. Wysocki J. J. Loferski P. Rappaport
High Temperature Improved Efficiency Photovoltaic Solar Energy Converter	US Govt Res Repts June 16 1961 LC $7.80 PB 154526	A zinc diffusion process for GaAs has yielded cells having up to 5.2 percent efficiency. The relationship between lifetime and spectral response is discussed.	J. J. Wysocki J. J. Loferski
Transistor Magnetic Inverter for Speed Control of AC Motors	US Govt Res Repts June 16 1961 LC $9.30 PB150792	The design and operation of a power inverter supplying a single phase reluctance motor is discussed.	N. I. Lyncki
Comparison of NPN Transistors and NPNP Devices as Twenty Ampere Switches	US Govt Res Repts June 16 1961 LC $4.80 PB155321	(No Abstract)	H. W. Henkels F. S. Stein
Study of Solid State Physics Approach To Development of Precision Variable Resistors	US Govt Res Repts June 16 1961 PB 155384	Magnetoresistance phenomena are considered and recent work in the field is surveyed. Consideration is given to InSb, InAs, and graphite as possible device materials.	(No Author Cited)
A Parallel Transistor Cascaded Amplifier for Controlling Very Large Currents	US Govt Res Repts June 16 1961 LC $1.80 BNL-4651	An AEC report.	R. H. Rhéaume
Transistorized Line-Operated Radiation Detection Instrumentation	US Govt Res Repts June 16 1961 OTS $1.00 HW 65553	An AEC report.	W. G. Spear
Solid State Research	US Govt Res Repts June 16 1961 OTS $2.25 PB171573	A quarterly progress report for the last quarter of 1960.	(No Author Cited)
Excess Carrier Lifetime In Indium Antimonide	US Govt Res Repts June 16 1961 LC $19.80 PB148016	A study of the temperature dependence of the lifetimes of excess carriers in InSb. A model is proposed which included a donor center having two energy levels within the forbidden gap.	R. A. Laff
Research on Thermomagnetoelectric Effects in Semiconductors	US Govt Res Repts June 16 1961 LC $1.80 PB152199	A study is made to determine the suitability of using thermomagnetoelectric and magnetoconductance effects to study the band structure of semiconductors.	P. Aigrain
Preparation of II-IV semiconductor Compound Mixtures and Measurements of Their Electrical and Thermal Properties	US Govt Res Repts June 16 1961 LC $3.30 PB150545	Techniques and problems of preparing single crystal samples of these materials is discussed.	H. Guennoc
Investigations of Surface Properties of Silicon and Other Semiconductors	US Govt Res Repts June 16 1961 LC $4.80 PB153849	Papers concerned with crystal structure, preparation techniques, heat treatment etc. as they affect the surface properties of the materials in question are included in this report.	H. E. Farnsworth J. A. Dillon Jr.

Market News . . .

Sales

The Electronics Division, BDSA, United States Department of Commerce, in its report of shipments of electronic components for the second quarter of 1961 has pointed out that the strong upward trend in unit sales of semiconductor devices has been accompanied by substantial price reductions. Unit shipments of germanium transistors increased 68 percent from the second quarter of 1960 to the same period of 1961; germanium diodes increased 66 percent; silicon transistors, 39 percent; and silicon diodes, 13 percent. However, during the past 12 months, average unit prices of germanium transistors decreased 31 percent; germanium diodes, 38 percent; silicon transistors, 34 percent; and silicon diodes, 31 percent. Declining prices caused a reduction of nearly 11 percent in total dollar volume of silicon semiconductor sales from a year ago, but despite falling prices shipments of germanium devices rose about 13 percent in total value.

Estimated Shipments of Semiconductors during the Second Quarter of 1961[1]

Category	Quantity (in thousands of units) Total	Military	Non-military	Value (in thousands of dollars) Total	military	Non-Mil
SEMICONDUCTOR DEVICES	123,240	32,507	90,733	146,041	58,507	87,534
Diodes and rectifiers	65.900	23,551	42,349	42,472	18,485	23,987
Germanium diodes and rectifiers	40,971	13,569	27,402	14,168	5,710	8,458
0-100 ma	36,247	[2]	[2]	12,168	[2]	[2]
Over 100 ma	4,724	[2]	[2]	2,000	[2]	[2]
Silicon diodes and rectifiers	24,929	9,982	14,947	28,304	12,775	15,529
0-100 ma	8,657	4,927	3,730	8,823	5,416	3,407
Recovery time: none, or over 0.1 usec	6,185	3,580	2,605	5,437	3,589	1,848
Recovery time: 0.1 usec and less	2,472	1,347	1,125	3,386	1,827	1,559
101 ma—1.4 amps	13,049	4,457	8,592	11,980	4,773	7,207
Recovery Time: none, or over 0.1 usec	12,364	4,119	8,245	10,917	4,163	6,754
Recovery time: 0.1 usec and less	685	338	347	1,063	610	453
1.5 amps—7.5 amps	467	250	217	1,170	590	580
Over 7.5 amps	2,756	348	2,408	6,331	1,996	4,335
Special semiconductor devices	8,196	1,677	6,519	20,260	7,775	12,485
Voltage regulator diodes	1,986	874	1,112	7,058	3,283	3,775
0-550 mw maximum dissipation	1,181	669	512	3,146	1,786	1,360
Over 550 mw maximum dissipation	805	205	600	3,912	1,497	2,415
Voltage reference diodes	187	44	143	1,286	367	919
Multi-layer devices (controlled rectifiers, PNPN diodes, and related devices)	279	50	229	2,386	585	1,741
Microwave diodes (mixers and detectors) and variable capacitance diodes (parametric diodes. harmonic generators, etc.)	748	403	345	2,116	1,697	419
Light sensitive semiconductor devices[3]	343	27	316	3,403	1,244	2,159
Other special semiconductor devices[4]	4,653	279	4,374	4,071	599	3,472
Transistors	49,144	7,279	41,865	83,309	32,247	51,062
Germanium	46,329	5,391	40,938	59,333	15,426	43,907
0-999 mw	42,441	4,844	37,597	48,454	12,265	36,189
0-29.9 mc	32,496	2,936	29,560	26,846	5,357	21,489
30-149.9 mc	6,626	794	5,832	10,845	2,502	8,343
150 mc and over	3,319	1,114	2,205	10,763	4,406	6,357
1 watt and over, all frequencies	3,888	547	3,341	10,879	3,161	7,718
Silicon	2,815	1,888	927	23,976	16,821	7,155
0-999 mw	1,644	1,027	617	9,668	6,008	3,660
0-29.9 mc	1,254	746	508	7,324	4,298	3,026
30-149.9 mc	354	255	99	1,948	1,428	520
150 mc and over	36	26	10	396	282	114
1-9.9 watts. all frequencies	1,007	741	266	9,648	7,195	2,453
10 watts and over, all frequencies	164	120	44	4,660	3,618	1,042

[1]Estimated total industry shipments including intra-plant and inter-plant transfers.
[2]Withheld to avoid disclosing the operations of individual firms.
[3]Includes solar cells, infra-red detectors, photoconductive cells, photovoltaic devices, photodiodes, photoelectric-magnetic devices, and the like.
[4]Includes diodes and rectifiers of selenium, copper oxide and other materials; tunnel diodes; thermoelectric semiconductor devices; and others not elsewhere classified.
Source: The quarterly Joint Survey of Production Capabilities for Electronic Parts conducted by the Electronics Production Resources Agency of the Department of Defense, and the Electronic Division, BDSA.

The Commerce Department has also reported that transistors are included among the top eight items showing a production growth of 30% or more between 1948 and 1960. Transistor output jumped from 1,318,000 units in 1948 to 127,928,000 units in 1960.

According to the latest figures released by the Marketing Data Department of the Electronic Industries Association, factory sales of transistors in August increased to 17,193,860 units, about 6 million more than the year's low of 11,227,388 units sold in July, when most plants shut down for vacation.

Total revenue accrued in August was $25,155,627. Transistors sold at the factory the month before were valued at $17,506,011.

Cumulative totals for this year continued to stay well ahead of those for the same period of 1960. Through August, 117,104,130 transistors were sold with a value of $199,781,787. Last year 77,289,-560 units worth $193,756,732 were sold.

A record output of 200 million transistors is estimated by Japanese electronics manufacturers for the 1961 calendar year according to a survey made by the Electronics Industries Association of Japan. The forecast is based on the output of 83,500,000 units during the first six months of this year and the present rising rate of production. It was predicted that more than three percent of Japan's transistor output for this year will be exported to the U.S. as component parts.

According to U.S. Bureau of Mines statistics, U.S. producers' shipments of Selenium during the period 1958 thru 1960, exceeded production and the excess demand was met out of inventories in the hands of producers and by imports, mainly from Canada. U.S. production of selenium in 1960 was 595,000 pounds, while shipments by U.S. producers amounted to 661,000 pounds. Inventory in the hand of U.S. producers at the end of 1960 was 273,000 pounds. During this same period imports totaled 162,000 pounds. During the first six months of 1961 the trend was reversed and U.S. production exceeded shipments by 75,000 pounds. The Bureau of Mines has also reported that the production and consumption of germanium last year was an estimated 54,000 pounds. Imports of germanium dioxide and metal were 52,198 pounds.

Suppliers

General Electric Co.'s new series of six planar, epitaxial, passivated silicon transistors are now available in production quantities. The P.E.P. series is designed for use in industrial and military high-speed switching and high frequency amplifier circuits.

General Thermoelectric Corp., Princeton, N.J., is marketing a thermoelectric cooling unit intended for use with stud-mounted diodes and transistors. In quantities of 100, these units are priced at $30.50 each.

Anchor Alloys, Inc., Brooklyn, N.Y., is now making semiconductor alloying spheres of 0.0005 inch diameters with purities greater than 99.999%.

Accurate Specialties Co., Inc., Hackensack, N.J., is now offering atomically interspersed, fold-tin eutectic preforms for fusing electrode attachments to semiconductor devices. This alloy is reported to wet uniformly, have a definite and reproducible melting point, and not be brittle.

Englehard Industries, Inc., Newark, N.J., has announced the formation of a Semiconductor Materials Department specializing in precious and base metals. Prototype and production orders are now being filled by the new facility in the firm's D. E. Makepeace Division, Attleboro, Mass.

Intermetallic Products, Inc., has been established by Joseph Waldman & Sons for the manufacture of bismuth telluride and gallium arsenide compounds and cooling modules. Assets, facilities and personnel of Crystal Labs, Inc., Riverton, New Jersey, were acquired in forming the new company. Their 5,000 square foot laboratory and pilot plant is located in Irvington, New Jersey.

Allegheny Electronic Chemicals Company, Bradford, Pa., is offering fully diffused silicon slices to semiconductor device manufacturers. The firm has available p-n-p and n-p-n junctions in addition to p on n and n on p junctions. Prices of the slices range from $4 to $8 each depending on the specifications and quantities involved.

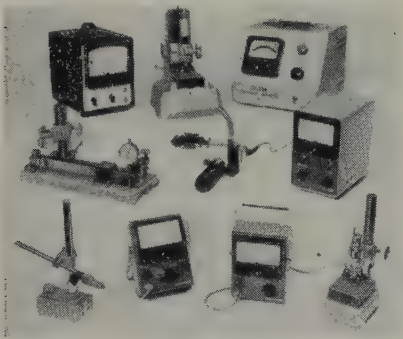
Texas Instruments Inc., has now made available their new n-p-n germanium mesa transistor TI2N797. This unit has been designed to complement high-speed p-n-p germanium epitaxials.

Sylvania has produced two new epitaxial germanium mesa transistors. Designated 2N781, 2N782 they claim to have switching speeds previously unattainable with germanium transistors and also provide exceptionally low saturation voltage at all current levels.

Electro Weld Co., Hawthorne, N.J., welder of transistor lead wires, has moved into its new 12,000 square foot plant.

New Products

Transistorized Gages

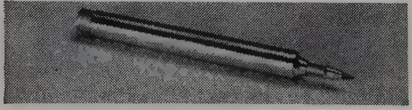


A new, completely transistorized line of electronic gages capable of measuring physical dimensions as small as two millionths of an inch (.000002") is being introduced by Techni-Rite Electronics, Inc. Featured is the Minicom System of interchangeable precision measuring units. This includes two Minicom Amplifiers, a choice of Minicom Height Gages, Bench Comparators, Dice Thickness Gages, and the Minigage Head. Small in size and light in weight, units are available in both 110 volts a-c or self-contained battery models.
Circle 78 on Reader Service Card

Gold/Boron Alloys

A new Gold/Boron alloy of high purity, for doping silicon devices, is now being produced to customer specifications by Alloys Unlimited. The alloy is used to insure P plus ohmic contact on the collector region in order to overcome negative impedance characteristics at the higher current levels. It consists of both boron in solid solution in the gold, and extremely fine grained boron particles homogeneously disbursed in the gold matrix. Foil of this alloy down to .0005 thickness can be produced. It can be clad down to 2/10 mil on a suitable substrate, and a wire down to .0015 diameter can also be manufactured.
Circle 120 on Reader Service Card

Bonding Machine Tool

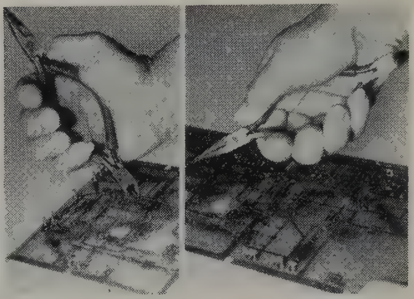


A new tungsten carbide-tipped capillary tube for use in semiconductor lead bonding machines is announced by Tempress Research Co., Inc. This new tool, which may be used for either "nail head" or "chisel" style thermal compression bonding of wires as small as 0.0005", is intended as a long life replacement for older type glass capillary tubes. The tool has a tubular stainless steel shank which fits all popular makes of lead bonding machines. The hard, wear resistant tungsten carbide tip threads into the shank and can be quickly removed and replaced with a new or different sized tip.
Circle 85 on Reader Service Card

Ultra Pure Arsenic

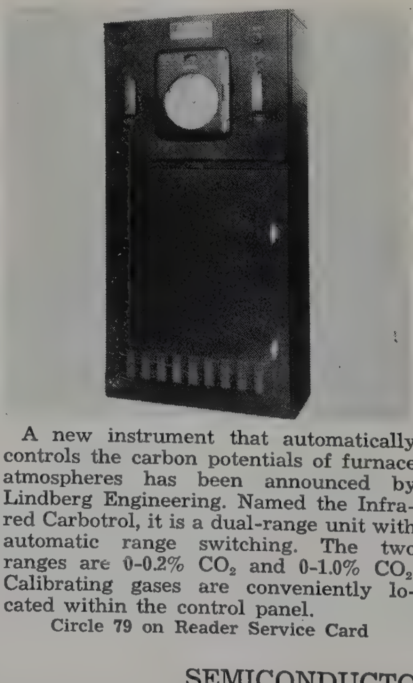
Cominco Products, Inc. is offering exact quantities of high purity arsenic packaged in break seal ampoules to meet specialized electronic requirements. Arsenic approaching 99.9999% purity is sublimed into evacuated quartz break seal ampoules and condensed at 450°C. This additional refinement eliminates the presence of residues, according to the manufacturer. Connecting tubes in three sizes allow the user to connect and transfer the arsenic in a controlled atmosphere to the desired equipment.
Circle 110 on Reader Service Card

'Double Ender' Plier



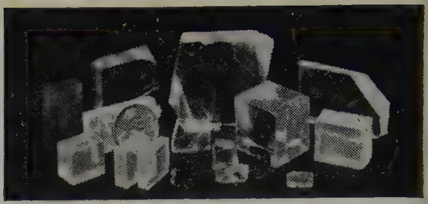
Hunter Tools has released a new tool which combines a fine cutting diagonal and a thin nose wiring plier. The 'Double Ender' is ideally suited for electronic assembly work, as it eliminates the operators from having to lay down one plier and pick up another every time they switch from a cut to a bending problem. The 'Double Ender' consists of two miniature pliers joined together at the tip of the handle and covered with a soft plastic grip.
Circle 94 on Reader Service Card

Furnace Atmosphere Control



A new instrument that automatically controls the carbon potentials of furnace atmospheres has been announced by Lindberg Engineering. Named the Infrared Carbotrol, it is a dual-range unit with automatic range switching. The two ranges are 0-0.2% CO_2 and 0-1.0% CO_2. Calibrating gases are conveniently located within the control panel.
Circle 79 on Reader Service Card

Magnesia Crystals

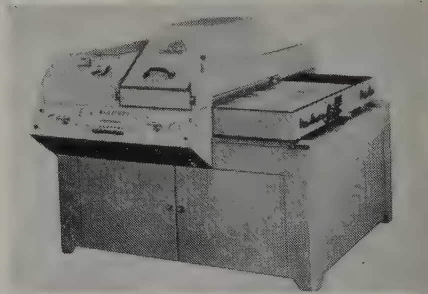


Relatively large, high purity, single crystals of Magnorite fused magnesia are being produced by Norton Company's Research and Development Department. Developmental quantities of these crystals, with dimensions up to ¾", are now available. At the present time, the major fields of application of these crystals seem to be where laser and maser studies are being conducted.
Circle 75 on Reader Service Card

Tantalum Capacitors

The Capacitor Division of General Instrument Corporation announces new and improved tubular sintered-anode tantalum capacitors. The new TAK-H capacitors operate at temperatures ranging from −55° C to +125° C at 70 volts or less without voltage derating; the TAK-C capacitors, from −55° C to +100° C at 85 volts without voltage derating; and type TAK capacitors from −55° C to +85° C. Type TAK may also be operated at temperatures up to 125° C by derating the working voltage.
Circle 86 on Reader Service Card

Microminiature Circuitry Production Machine



Leading manufacturers of microminiaturized components for electronic circuitry are turning to automatic step-and-repeat photography to facilitate rapid, accurate production of these critical parts, according to Royal Zenith Corp., distributor of the Misomex, a precision step-and-repeat machine. The step-and-repeat method is used to achieve multiple identical images from a single piece of original artwork, which is photographically reduced and then automatically stepped up on the Misomex at the rate of 350 exposures per minute to an accuracy of .001" over the entire exposure area. For further microminiaturization, the resulting film is then once again reduced and stepped up on the Misomex to produce the complete pattern, in negative or positive form, which is then exposed on the metal wafer, treated with a photo-resist.
Circle 77 on Reader Service Card

Zener Diodes

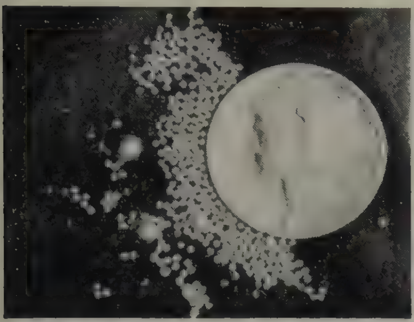
Especially produced for the commercial market, a new line of Zener Diodes by American Semiconductor Corp. has a voltage range of 2 thru 350, a 200 mw rating, and a voltage tolerance of 20%. Operating temperatures range from −55°C to +150°C. Also available in 10% and 5% tolerances.
Circle 96 on Reader Service Card

Planar Epitaxial Passivated Transistors

General Electric Company has announced a new series of planar, epitaxial, passivated silicon transistors designed for use in industrial and military high speed switching and high frequency amplifier circuits. They operate at frequencies from 50 mc to above 120 mc. This P.E.P. series includes 6 types, 2N2193 through 2N2195 and 2N2193A through 2N2195A. They are capable of dissipating 2.8-watts with case temperature of 25°C, are rated for operation from −65°C to +200°C, and for storage from −65°C to +300°C. The company has also announced seven silicon planar transistors, types 2N696 through 2N699, 2N1613, 2N1711 and 2N1893. They have a power dissipation rating, at a case temperature of 25°C, of 2-watts.

Circle 117 on Reader Service Card

Solder Brazing Spheres



Semi-Alloys, Inc., offers solder and brazing alloy spheres in sizes from .0005 to .125" in diameter. These spheres, developed to meet exacting requirements for special applications, have been instrumental in speeding automatic production facilities. Stock samples of some alloys, which may be used to evaluate adherence to size and spherosity will be sent free of charge to individuals addressing their request on company letterhead.

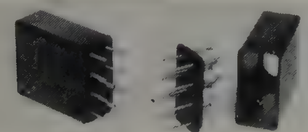
Circle 104 on Reader Service Card

Germanium Diodes

A new type of germanium diode, capable of withstanding the extremely high stresses encountered in missile and computer applications, has been announced by National Transistor Mfg., Inc. Called "Super G Diodes," because of their extremely high ruggedness and reliability, the new circuit elements have all of the desirable characteristics of gold bonded diodes; however, their resistance to shock and mechanical stress is several times greater, according to company officials. They reportedly withstand stresses in excess of 50,000 G's.

Circle 119 on Reader Service Card

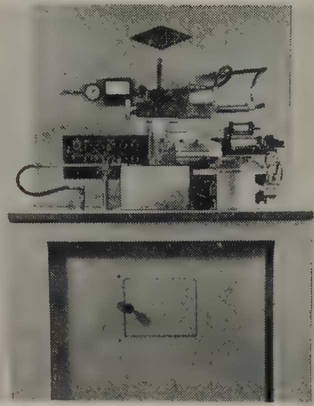
All Epoxy Module



All epoxy module packages (headers and cases) which will plug into standard 8 or 10 pin crystal can relay sockets are now available from Epoxy Products Division, Joseph Waldman & Sons. A friction fit between the header and the case prevents liquid epoxy from leaking during encapsulation. It will withstand continuous operating temperatures of 400° F. With an epoxy encapsulant it will withstand temperature and humidity cycling in accordance with all applicable MIL specs.

Circle 90 on Reader Service Card

Wafering Machine



A new type wafering machine, the Hamco Dia-Saw, which overcomes many limitations in equipment using I.D. type saws has been introduced by Hamco Machine & Electronics Corp. Precise tensioning can be accomplished off the machine, making it possible to apply a thoroughly uniform tension under extremely accurate and close control throughout a complete 360°. Down-time is reduced to a bare minimum. The entire tension mount can be replaced in a minute or two. Evenly applied tensions and a new type wheel centering device makes tensioning even the thinnest blades a simple matter. Billets of any length can be cut. A complete cut-off of each wafer is accomplished.

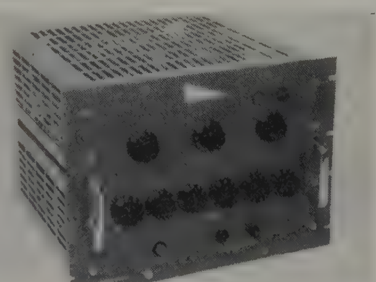
Circle 121 on Reader Service Card

Electron Gun For Microcircuit Manufacturing

Rescon Electronics Corporation has developed an electron gun and transport mechanism which makes possible the continuous evaporation of metallic, as well as dielectric materials, in the mass production of thin-film microcircuit elements. The material to be evaporated is in the form of a continuous tape which is passed in front of the electron beam at its focal point. Temperatures in excess of 10,000° Kelvin are produced at the smallest spot size. The electron gun is a pulsed triode operating at 55 kilovolts peak with a beam current of 1 to 10 milliamperes.

Circle 82 on Reader Service Card

Current Governor



A programmable constant current source has been introduced by North Hills Electronics, Inc., designed especially for gyros, semiconductors and magnetic components. Model CS-141 Current Governor furnishes currents from 0.1 μa to 1000 ma for load voltages from 0 $\pm$100 volts. Accuracy at any current setting is 0.02% F.S. Line and load regulation are better than 0.0025% for d-c outputs. The unit may be used as an a-c current source from d-c to 6 KC by driving it from an external modulating signal.

Circle 105 on Reader Service Card

Transistor Checker

Instant Circuits Model 29 Transistor Checker, weighing less than 2 lbs., enables the user, by simply pushing a button and reading a meter, to quickly evaluate the most significant characteristics of a transistor. Measuring 6¼" x 3¾" x 2¼", this ICC instrument features a self-contained power supply (4.5 vdc), a two-way linear and triangular socket and pin tip jack permitting the use of plug-in test clips for connection to transistors with long leads or nonstandard pin arrangements. Tests all general purpose, audio, RF, low power and switching transistors of both n-p-n and p-n-p types.

Circle 106 on Reader Service Card

Dual-Trace Oscilloscope

A complete pulse-sampling system with risetime of 0.35 nanosecond, the new Tektronix Type 661 Oscilloscope meets most general-purpose-measurement demands in repetitive-signal applications today. Characteristics include capabilities for triggering externally, or internally on either A or B trace, for observing equivalent sweep times from picoseconds to a millisecond, for displaying repetitive signals from fractions of millivolts to volts, for measuring risetimes from hundreds of picoseconds to a millisecond, with uniform, high writing rate at all sweep speeds over the full 8-centimeter by 10-centimeter display area.

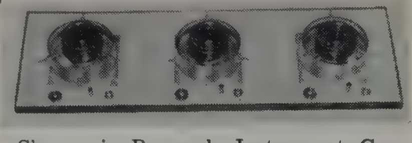
Circle 93 on Reader Service Card

Air Velocity Meter

Flow Corporation Flowtronic 55 Series Air Velocity Meter provides direct readings of air velocities from 0-4000 fpm and air and surface temperatures from 20° F to 220° F. An eight transistor circuit provides rapid and damped meter response and an electrical output whose response is d-c to 1 kc. The instrument is powered by 115 v.a.c. or by rechargeable nickle cadmium batteries. High sensitivity at low air velocities is featured.

Circle 88 on Reader Service Card

Lapping Machine



Shown is Research Instrument Company three-head Lapping Table. Each head is a complete integral lapping unit. Laps are 7", however, the basic head is ample enough to take up to a 9" to 10" lap. Motor drive is through a variable speed d-c gear head motor. Machine speed, 280 rpm maximum. Lapping head was designed primarily for Germanium and Silicon.

Circle 98 on Reader Service Card

(*Continued on page 53*)

Industry News
(from page 15)

RESEARCH and DEVELOPMENT

In a National Bureau of Standards program of fundamental research in metal physics, a study was recently made of the growth of zinc crystals from the vapor phase. Growth rate data from experiments conducted by R. L. Parker and L. M. Kushner of the Bureau staff were found to be in good qualitative agreement with the screw dislocation theory of crystal growth as modified by impurities, and to show no evidence of surface nucleation effects. These results, among the first of this type to be obtained on monatomic systems, provide information on the mechanisms involved in the metallurgically important process of crystallization, and they will be of considerable value in other studies now under way on the growth kinetics of potassium crystals and of mercury "whiskers."

Ultrasonic waves have been amplified directly in a piezoelectric semiconductor crystal by Bell Telephone Laboratories scientists. The sound waves are amplified by interaction with electrons drifting in the crystal, in much the same way that electromagnetic waves are amplified in a traveling wave tube. A new class of solid-state electronic devices such as amplifiers, oscillators, delay lines and isolators now appears possible based on the combination of piezoelectricity and semiconduction in certain crystals.

A multi-purpose "crystal grower," that combines in one unit operations that previously required four separate and expensive pieces of equipment, has been developed for the U.S. Air Force by ITT Federal Laboratories, Nutley, N.J. Designed by scientists in the Basic Sciences laboratory of this New Jersey division of ITT, the machine is capable of producing near-perfect crystals such as rubies, sapphires and other monocrystalline materials for use in basic research as well as functioning electronic communications systems.

The four growing methods, all available with the ITT equipment include:

1. The Czochralski method in which the crystal is grown, when a seed of the crystal material is slowly withdrawn from a high temperature melt of the material.
2. The "floating zone" method wherein a single-crystal bar and polycrystal bar are butted together and the junction melted by radio frequency induction. The molten zone is slowly moved into the polycrystalline region to form the new crystal as the trailing side cools.
3. The "horizontal zone leveling" method which is the same as above, except that a container is used in holding the material in order to form larger crystals.
4. The newest process, which is best for some purposes, is called the Bauer-Marino method, after the two ITT employees who invented it, Dr. W. H. Bauer and Anthony J. Marino. In this method, powdered crystal material is sifted through a loop heated by radio frequency to high temperatures and, under controlled conditions, the crystal is formed as the materials cool.

The Bauer-Marino method is a major improvement over previous ones since it does away with gas-fed flame as a source of heat which, combined with control and enclosure difficulties, usually resulted in impure crystals with structural imperfections.

The Aeronautical Systems Division, U.S. Air Force, and Texas Instruments Incorporated, Dallas, Texas, recently demonstrated in operation a microminiature digital computer utilizing semiconductor networks. The advanced experimental equipment has a total volume of only 6.3 cubic inches and weighs only 10 ounces. It provides the identical electrical functions of a computer using conventional components which is 150 times its size and 48 times its weight and which also was demonstrated for purposes of comparison. It uses 587 digital circuits (Solid Circuit semiconductor networks) each formed within a minute bar of silicon material. The larger computer uses 8500 conventional components and has a volume of 1000 cubic inches and weight of 480 ounces.

The new products laboratories of Westinghouse Electric Corporation have delivered to the Bureau of Ships, U. S. Navy, a portable "back-pack" thermoelectric generator. The generator is an experimental electric plant capable of producing militarily useful amounts of power, yet is light enough in weight to be carried by one man. The generator burns bottled propane gas and can be adapted to burn ordinary gasoline. Solid, semiconductor-type materials change the heat of the gas flame into electricity when a difference in temperature is maintained across them. A small fan, taking its power from the generator, blows air across the cool side of the materials.

The new "back-pack" generator develops a gross of 340 watts of electric power. Eighty watts are used to drive the fan. The generator operates at an average temperature of 842°F (460°C) on its hot side. The cool side of the unit runs at 284°F (140°C). Exclusive of its gas tank and mounting frame, the portable power plant weighs 36 pounds. Its 450 thermoelectric couples are mounted hexagonally around the gas burner, giving a structure 11 inches in diameter and 22 inches long.

New Products
(from page 51)

Transistor Tester

A new semiconductor and component inspection system has been introduced by Texas Instruments Incorporated. The new instrument features fast d-c sequential testing, printed circuit card programming and automatic sorting. It was developed by the Industrial Products group of TI's Apparatus division. Model 654 is a fast go-no-go instrument capable of making up to 15 sequential d-c tests on two and three terminal units. The new system can test 1800 devices per hour and has a capacity of 27,000 tests and sorts per hour. The time of each of the 15 tests can be independently programmed from 50 milliseconds to 3 seconds. Three terminal tests can be made at any or all 15 positions.

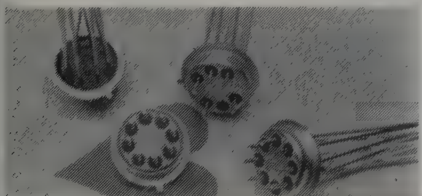
Circle 108 on Reader Service Card

Laminated Plastic Work Surfaces

Sturdilite Products, Inc. announces a new line of high pressure plastic laminated Work Surfaces for industry. The tops are constructed 2" thick with a solid lumber balanced core. They are non-conductive and highly resistant to heat, stains and scratches. These work surfaces are ideal for use in electronics, nuclear and missile plants, for production, inspection, white rooms, laboratories, etc.

Circle 114 on Reader Service Card

Transistor Closures



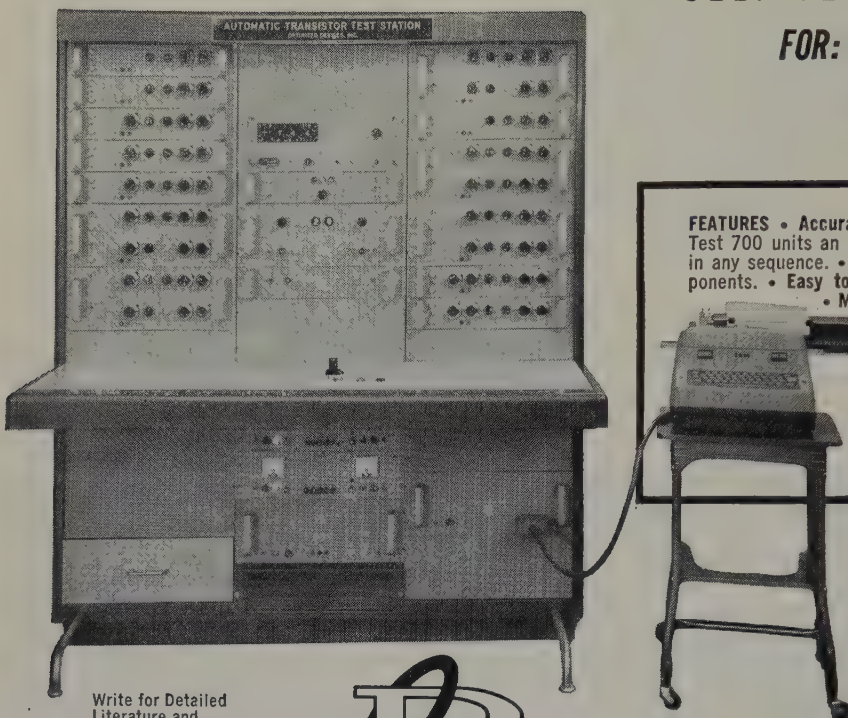
Glass-Tite Industries, Inc., can now accommodate up to thirteen separate leads in a closure conforming to the basic TO-5 transistor configuration. Leads may be grounded or ungrounded, depending on design requirements. Measuring no more than 0.300" in body diameter (exclusive of flange), and 0.100" high, the header can be supplied with electrically isolated flat forms or "islands," or with a common body. These units are ideal for multiple transistor packages, self-contained logic circuits, diode networks, molecular wafers, and miniature networks.

Circle 97 on Reader Service Card
(Continued on page 56)

Precision AUTOMATIC TRANSISTOR/DIODE TESTER

SELF-TESTING AND FAIL-SAFE

FOR: Reliability Testing • Incoming Inspection • Production Testing Engineering Studies



FEATURES • **Accurate:** 1% on d.c. tests, 3% on a.c. • **High Speed:** Test 700 units an hour. • **Increased Capacity:** Up to 25 individual tests in any sequence. • **Versatile:** Choice of measurements by modular components. • **Easy to Program:** By 10 turn dials and selector switches. • **Modest Cost:** Approx. $10,000, depending on modules.

PARTIAL SPECIFICATIONS

Power Ratings 0-200 v, 0-1 amperes. Other powers available by substitution of power supplies.

Measurements Include ICBO, ICEO, d.c. Beta, VCE Sat., VBE Sat., BVCBO, BVCEO, BVEBO. h11, h21, h12, h22, VPT.

Each system assembled from standard modules to meet particular requirements. Output choice is Go, No-Go; digital indication; printout; card or tape punch; or bin selection.

Write for Detailed Literature and Specifications to Dept. SP

OPTIMIZED DEVICES INC. THORNWOOD, NEW YORK ROgers 9-6110

Circle No. 23 on Reader Service Card

Introducing an alligator clip with a "microscopic tip"!

the Mueller MICRO-GATOR

Here is the alligator clip you can now use where no other clip will do! On printed circuits, in tight spots and on tiny terminals too crowded for anything but its "microscopic" tip. Fully insulated right down to the nose. It offers all the speed, free-handed ease and convenience associated with other Mueller alligator clips.

Strong new type "keyed in" hinge. Traditionally snappy Mueller spring. Clinching ears for gripping wire.

Tough, Vinyl, skin-tight insulator. Lip-action tip-slot. A ringer for the popular "Mini-gator" insulator.

INSULATORS SOLD SEPARATELY. (Standard Red and Black colors. White, Blue, Yellow and Green also available.)

FREE SAMPLE of clip and insulator, on request to factory

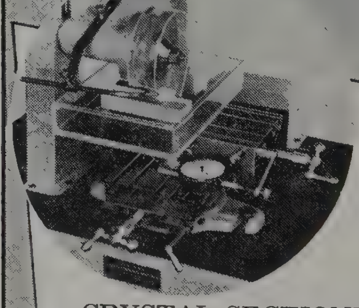
Mueller Electric Co.

1590H East 31st Street, Cleveland 14, Ohio

Circle No. 24 on Reader Service Card

GILLINGS-BRONWILL

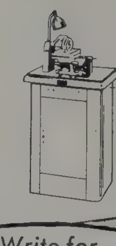
THIN SECTIONING MACHINE



FOR RESEARCH AND PRODUCTION

CRYSTAL SECTIONING .005″ to .010″

Cut sections as thin as .005″ practically plano-parallel from blocks ¾″ x 1½″ x 3″ in less than 5 minutes with this 6500 RPM 4″ x .012″ diamond wheel. Automatic, two direction, precision table feed. Rate of feed set from ⅜″ to ¾″ per minute. ¼ H.P., 115 volt, rubber mounted motor. Immediate delivery.



Write for Specifications

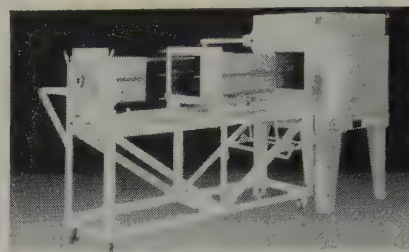
BRONWILL SCIENTIFIC
Division of Will Corporation

Circle No. 25 on Reader Service Card

New Products

(from page 53)

Furnace Conversion Accessory



A new Conversion Accessory announced by The Pereny Equipment Co., Inc., provides for retort heating in a standard Pereco General-Purpose Electric Furnace. The unit consists of an alloy retort mounted on a movable rack fitted with casters. When the main furnace door is open and swung out of the way, and the conversion unit is wheeled and locked into place, the furnace is then ready to perform work in closely controlled protective atmosphere at any temperature up to the capabilities of the alloy muffle.

Circle 100 on Reader Service Card

Filter Systems

Utilizing lucite, epoxy, teflon, neoprene, hypalon and kel-f components for the pump and filter chamber as required, Sethco Mfg. Corp., has introduced a new series of Self Priming "All-Plastic" Filter Systems that provide crystal clear depth filtration for many problem industrial liquids. The standard models are designated as the LPNI series and feature "full-view" lucite filter chambers and polyethylene pump bodies with neoprene impellers. Model LPNI-30 has a capacity of 100 GPH. Other models are available with capacities from 25 to 1200 GPH, and in materials of construction suitable for higher operating temperatures and extremely corrosive solutions.

Circle 83 on Reader Service Card

Voltage Indicator

The Regent Automatic Maximum Transient Voltage Indicator, Model TD761M2, is a fully transistorized, battery operated portable instrument, particularly useful to semiconductor engineers. It will indicate automatically the maximum level of transients, of 1 usec. or greater duration, up to 2,000 volts, in any part of a circuit. It also indicates the peak value of any voltage wave form including d-c.

Circle 107 on Reader Service Card

Drafting Symbols

A new electronic circuit template is available from the Quintec Instrument Company. Designed especially for semiconductor circuit drafting the Symbol-Ease template provides the latest transistor and diode symbols in addition to those for electron tubes and electronic components. Symbols are in accordance with MIL-STD-15A, ASA and IRE standards for electronic and semiconductor graphic symbols and are sized for the 0.2" grid.

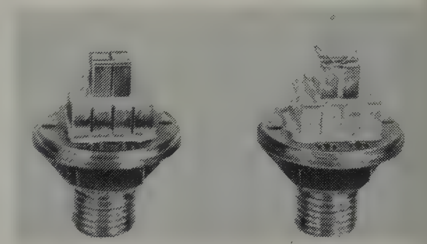
Circle 91 on Reader Service Card

Transistor Bases

Electrical Industries line of hermetically sealed transistor bases includes types for Jedec Series T05, T09, T018, T033 and T046 packages, miniatures for hearing aids and other applications, and bases for practically all military and commercial requirements. Standard lead lengths are offered in a variety of modifications to provide complete design flexibility. The new transistor bases come in a broad selection of terminal configurations. Finishes include Brite Gold, electro-tin and high purity gold for direct fusion of semiconductor elements to header base. Special plating can be supplied on order.

Circle 95 on Reader Service Card

Thermoelectric Coolers



A new line of 2 & 3 stage cascade thermoelectric coolers that will reach −95°C from a sink temperature of +20°C with an input of only 3.0 amps max. is available from Jepson Thermoelectrics, Inc. Varying the current varies temperature. These lightweight coolers eliminate the comparatively immense weight and bulk of CO_2 cooling systems and storage tanks formerly required to cool infra-red and photoelectric cells and parametric amplifiers in missile and commercial applications, according to the company.

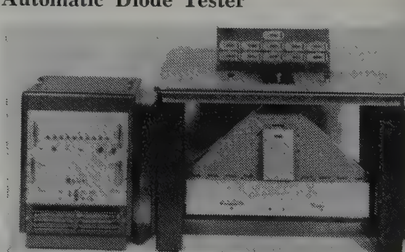
Circle 115 on Reader Service Card

Transistor Mounts

Admiral Plastics Corp., has announced four new standard designs of Transistor Mounts for use with TO-5, 9, 12 and 18, Triode Solder Seal and Oval Welded Silicon Transistors. These are valuable for increasing functional reliability of transistors, preventing short circuits, and reducing insulation and vibration problems. Recommended for rigid, insulated, vibrationless mounting of transistors having a lead-base diameter of .100" and .200", universal 5-hole pattern accommodates parts of various sizes and configurations having 3 or 4 leads.

Circle 101 on Reader Service Card

Automatic Diode Tester



Atlantis Electronic Corporation announces Model T-501A Automatic Diode Tester. The Tester automatically sequences through 10 tests and sorts into 19 "good" categories (storage bins) plus "reject" at the rate of 3600 diodes per hour. Tests may be any combination of inverse or forward. Automatic orientation check is performed prior to each test sequence. "Open" and "shorted" diodes are immediately rejected without the test sequence being performed.

Circle 111 on Reader Service Card

Industrial Gold Plating

Lea-Ronal, Inc. has announced the development of gold electroplating process designated Aurall Gold. The deposits secured from the Aurall Process have met the most exacting requirements for numerous electronic parts such as required for semiconductors and instrumentation. Aurall Gold is a pure 24 Karat gold plate without any alloying elements. The deposits are lustrous, show excellent ductility and are remarkably free from porosity. On Kovar, Aurall gold deposits will not be discolored at elevated temperatures of 550°C.

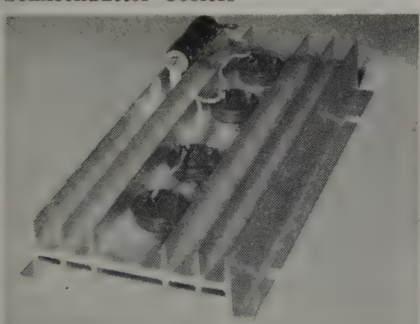
Circle 109 on Reader Service Card

Diode Testers & Classifiers

The Transistor Automation Corp., line of d-c Automatic Testers and Classifiers for Diodes consists of several models to serve Production, Engineering and Inspection with the highest degree of accuracy, reliability and speed. In the basic machine common to all models, the handling of diodes is completely automatic, eliminating manual loading of individual diodes and human errors that often occur in sorting operations. Diodes are loaded in bulk lots of several thousands at a time and fed automatically through a test station where all the required tests are performed. After testing, the diodes are sorted in appropriate bins. Up to 16 classifications are available. Production rate is adjustable from 2000 to 7000 per hour depending on tests performed and model used.

Circle 76 on Reader Service Card

Semiconductor Coolers



Anderson Machine Inc., has entered the field of manufacturing Semiconductor Coolers (Heat Sinks). Models #10106 and #20107 are natural convection coolers which lend themselves equally well to forced convection requirements. Natural convection thermal resistance as low as 1.5° C/W. Thermal resistance as low as 0.3° C/W, with moderate air flow. Ideally suited for Transistors, Zener Diodes, Silicon Control Rectifiers, and Power Rectifiers and Diodes.

Circle 80 on Reader Service Card

Microwave Detector

The new "Bolomistor" introduced by Microwave Semiconductor & Instruments, Inc. pioneers the use of thermal-responsive devices for the detection of microwave energy. Thermoelectric semiconductors (typified by lead telluride) have been successfully used in microwave applications. The time constant of the "Bolomistor" microwave detector is on the order of 1 microsecond. It exhibits no rectification curve, but rather a steady resistance ranging from 2 to 4 ohms when encapsulated in a crystal diode package such as used for the 1N23. The device is immediately applicable in power measurements from 3,000 to 10,000 mc in existing crystal holders and amounts.

Circle 92 on Reader Service Card

Ultrasonic Cleaner

The diSONtegrator System 320 industrial sized 5-gallon capacity ultrasonic cleaner, has been introduced by Ultrasonic Industries Inc. Guaranteed for five years, it features broad band frequency modulation which eliminates the need for automatic tuning, prevents overloading of transducers, excites them at optimum frequency for maximum activity and adds to longevity. The generator is rated at 320 watts average power, 1280 watts peak power output. Fused for 7 amps, the generator operates from 117 volt-50/60 cycle line current.

Circle 87 on Reader Service Card

Furnace Floor Models

L & L's Dyna-Trol furnaces have been designed and constructed for special use in research and laboratories. Dyna-Trol is a small, compact furnace which heats up to 2000° F in one hour; 2300° F in one and a half hours. A constant level of temperature, and infinite heat-rate control ranging from 300° F to 2300° F, can be maintained by means of input controllers. These can be set at from 7% to 100% of input.

Circle 84 on Reader Service Card

Semiconductor Tester

Atlantis Electronics T-350 Semiautomatic Semiconductor Tester consists of a 12-test sequence for both transistors and diodes and an automatic 4-bin sorter. It performs 12 transistor tests, which may consist of as many as 10 two-terminal tests and 6 three-terminal tests, with the combined total not to exceed 12 tests; and 12 diode tests, which may consist of as many as 10 inverse tests and 6 forward tests, with the combined total not exceeding 12 tests.

Circle 81 on Reader Service Card

Dual High Vacuum System

Dual 12 Vacuum System, designed to produce a vacuum of 1 x 10^{-4} mm Hg in less than 10 minutes and 5 x 10^{-5} mm Hg in less than 20 minutes, has been announced by Vacuum Equipment and Components, Division of Suburban Plastics Co. Inc. The System was developed specifically for depositing thin films on electronic components. It consists of two independently operating units mounted on a common frame. The electrical system consists of a 2 KVA variable transformer and 2 KVA 5-10-20-40 volt step-down transformer.

Circle 112 on Reader Service Card

BACK ISSUES

1.00 Each

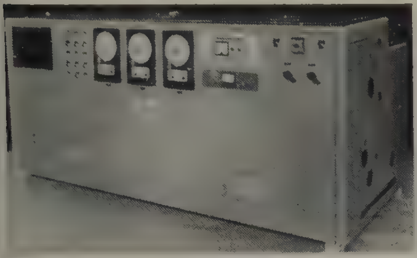
1958—Jan/Feb; March/April; May/June; Nov/Dec.
1959—Dec.
1960—March, May, June, July, Aug., Sept., Nov.
1961—Feb., Mar., April, May, June, July, Aug., Sept., Oct., Nov.

SEMICONDUCTOR PRODUCTS
Back Issue Dept.
300 W. 43 St. New York, N. Y.

Semiconductor Technology

Vacuum processing has been put on a fully automated continuous basis with the start up and successful operation of a C. I. Hayes Model VAC-50C Vacuum Conveyor Furnace at the Newark, New Jersey plant of General Instrument Corporation.

Except for loading and unloading, the entire furnace operates automatically. The worker periodically places "boats" onto an external conveyor which automatically injects them into a vacuum-lock inlet. From here work is belt-conveyed through the heat zone where it undergoes processing temperatures up to 1,000°C and is then returned to atmosphere through the vacuum-lock outlet. Set temperatures



are maintained within ±1°C by means of proportional control instruments which govern three heat zones within the furnace. Control is by the three-mode system: rate, reset, proportional band. Control characteristics may be "tuned" by varying bias control and current limiting.

Close tolerance temperature control combines with split-second timing of work conveyance to provide maximum yields of top quality diodes. Actual experience is proving that the furnace can attain pressures to 5 × 10^{-6} mm. Hg. and maintains operating pressures to 5 × 10^{-5} mm. Hg. under load continuously and dependably. Model VAC-50C is processing 34 "boats" per hour, with 250 to 300 diodes per "boat." According to the company, output of unexcelled quality at a rate as high as 80,000 diodes per 8 hour shift is being obtained.

Circle 185 on Reader Service Card

Applications

(from page 38)

creased stability. The same principle of trading power gain for stability can be used in the common-emitter circuit.

Current Feedback

The common-base connection has built-in current feed-back effective at high frequencies. While this feedback lowers the input impedance in the common-base circuit, it can be made to increase the input impedance in the common emitter by the addition of a small, unbypassed emitter resistance of 5 to 50 ohms. The increased input impedance helps decrease the impedance ratio, which means either more power gain or stability as desired.

Personnel Notes

Will Corporation officials in Rochester announced the appointment of Robert D. Quigley as Manager of its Bronwill Scientific Division, created to market a highly specialized line of foreign and domestic laboratory apparatus. Mr. Quigley succeeds former Manager R. L. Sweet.

Appointment of Julian Hilman as Director of Reliability of the General Instrument Corporation Semiconductor Division, has been announced by the company. The special Reliability Department which Mr. Hilman heads up was established to analyze and evaluate process techniques, materials and test and rating procedures for devices manufactured for missile and satellite applications at the Semiconductor Division's three major plants in Newark, N.J., Hicksville, N.Y., and Woonsocket, R.I.

Harold R. Montgomery has been appointed manager of electric furnace plants for Norton Company's Abrasive Division. His headquarters will be at Chippawa, Ontario. Other plants for which he is responsible are at Cap-de-la-Madeleine, Quebec, and Huntsville, Alabama. He will have charge of electric furnace plant operations for the production of crude abrasive and refractory materials.

Stephen Bukata has been named Director of Research and Development for Tri Metal Works, Inc., Riverton, N.J., it was announced by Rowen Stuffer, company president. Tri Metal manufactures high vacuum ovens and specialty equipment for use in the electronics field, as well as custom vacuum brazing of honeycomb panels in aluminum and stainless steel. Mr. Bukata now has three patents pending in the U.S. relative to honeycomb brazing, and has also filed patents in seven foreign countries. At present he is designing a complete new line of oil vapor diffusion and booster pumps for high vacuum work.

Thomas M. Darby has been appointed General Manager of Allegheny Electronic Chemicals Company, succeeding William M. Brewster. Mr. Darby has had extensive experience in the silicon materials business. He was associated with Texas Instruments, Inc., for over four years, where he held various high level positions in production, financial planning, control and marketing.

Appointment of two branch industrial sales managers and an account executive has been announced by Minneapolis-Honeywell Regulator Company. The new industrial sales managers and branch offices they head are Donald B. Sharman, San Francisco, and Jack Phillips, San Diego. William N. Wallace is the account executive for scientific sales with offices in Santa Clara.

The appointment of James O. Lawson to the newly created position of manager of quality control for the Parts Division of Sylvania Electric Products Inc. has been announced. Louis R. Wanner, chief engineer of the division, said Mr. Lawson will be responsible for the coordination of the quality control programs of the nine plants in the division. He will make his headquarters in Warren, Pa.

Personnel Notes
(continued)

Walter L. Doelp, Jr., has been promoted to assistant to the director of semiconductor research and development, Lansdale Division, Philco Corporation, a new position. In making the announcement, Dr. C. G. Thornton, director of semiconductor R & D, explained that Mr. Doelp will assist in overall management of laboratory operations. In addition he will act as liaison between the laboratory and other company activities.

The promotion of several staff members to key management positions in support of the new organizational structure of The Daven Company, a member of the General Mills Electronics Group, was announced by Kenneth J. Carlson, General Manager: Bernard J. Perry, Director of Operations, Manchester, N.H., Albert M. Steinbach, Director of Operations, Livingston, N.J. Berj Matossian has been promoted to Chief Engineer of Livingston Operations, replacing Richard J. Newman, whose promotion to Director of Planning and Development was previously announced.

Dr. George T. Murray has been named vice president of research of Materials Research Corporation, 47 Buena Vista Avenue, Yonkers, N.Y. For the past three years, Dr. Murray has served as Director of Research at MRC where he has conducted major programs in the fields of reactor diffusion studies and ceramic ductilization.

Joseph Oppenheim, veteran Raytheon engineer and programs manager for the Aero/Weapons division, has been promoted to the newly created post of director of programs management for the company's Electronic Components and Devices Group. H. R. Oldfield, Jr., vice president and group executive, said the position had been established to promote closer liaison and insure effective cooperation among the components businesses of Raytheon, and to provide closer coupling to major systems users of these components.

Victor Fong of Somerville, New Jersey, has been appointed manager of Device Fabrication for Clark Semiconductor Corp., Clark, New Jersey, it was announced by Herbert Miller, President. Mr. Fong will be in charge of the production of the company's high frequency power transistors. Before joining Clark, he was an engineer for RCA Semiconductor Division and did development work for Bell Telephone Laboratories.

Albert Yvon Fournier has been appointed to the newly-created post of development engineer at Anchor Alloys Inc., it is announced by Herbert Drapkin, president. Mr. Fournier will head up the company's development program in semiconductor materials. The firm, located at 968 Meeker Avenue, Brooklyn, specializes in the alloying and formation of materials used in electronic equipment, communications, data processing, aircraft and missiles.

John L. Richmond has been appointed manager of the neutron sources department of Monsanto Research Corporation's Dayton Laboratory, Dr. E. N. Rosenquist, laboratory director, has announced. Mr. Richmond will be in charge of production and sale of radioactive sources, which MRC recently announced it would manufacture at the Dayton location.

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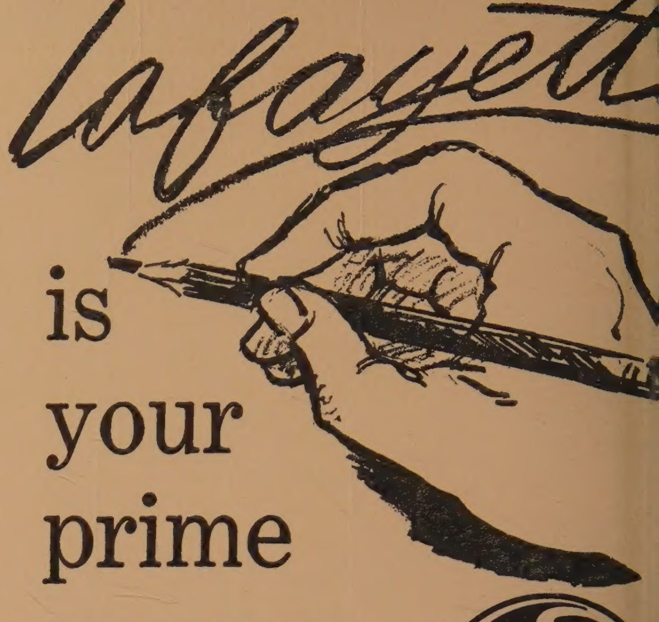

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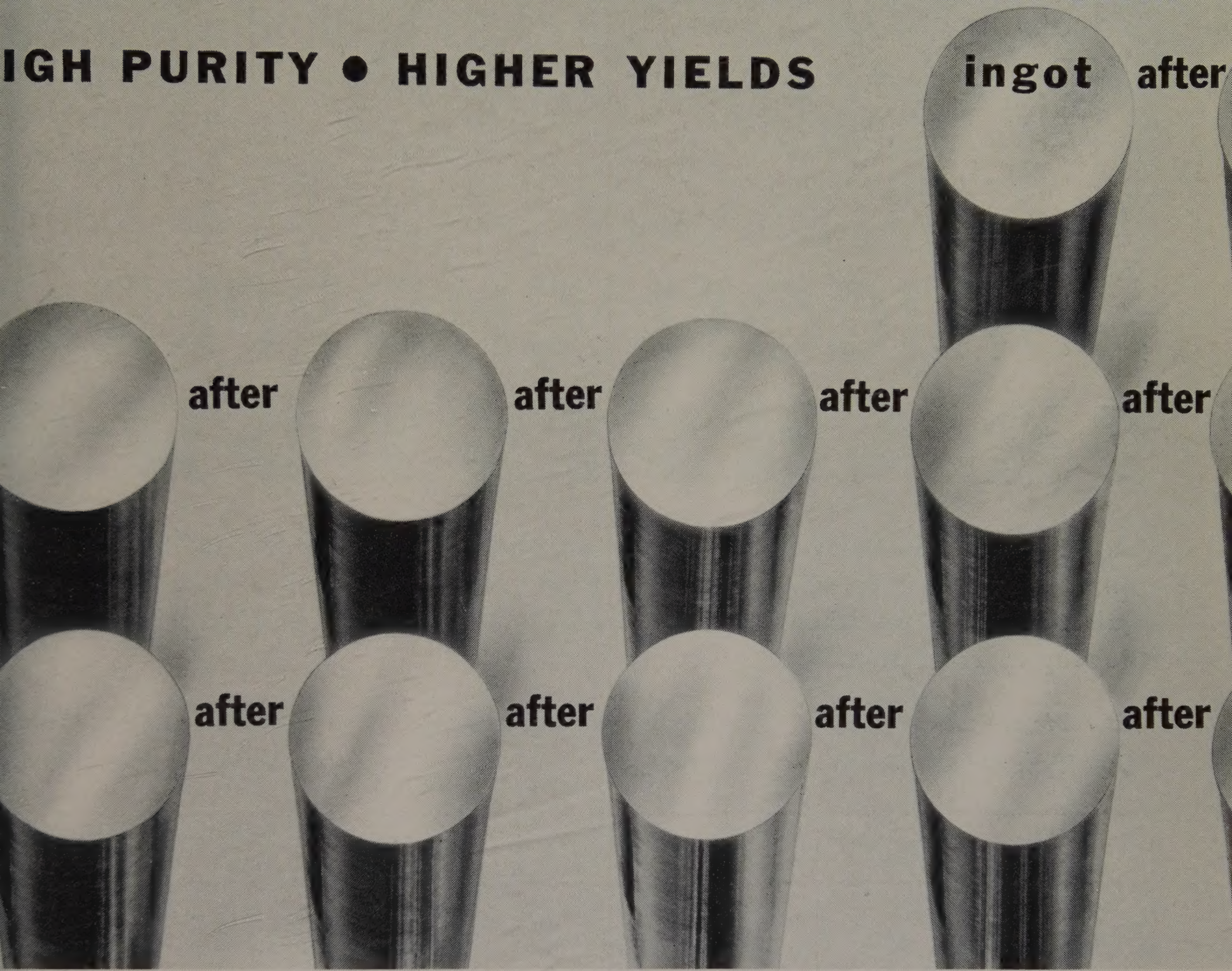

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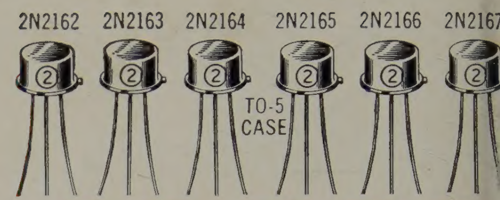

SILICON CHOPPER TRANSISTORS

Sprague Surface Precision Alloy Transistors are especially designed for low-level chopper applications. Their specifications have been tailored to meet your actual circuit requirements. Compare these standard Sprague units with ordinary alloy devices for the following characteristics:

- **Low Offset Voltage**
- **Low Dynamic Resistance**
- **Low Output Capacitance**
- **Low I_{CBO}**
- **High Frequency Response**
- **Matched Pairs Available**

TYPE	Min. BV_{CBO} (Volts)	Max. I_{CBO} (μa)	Max. V_{EC} (mv)	Min. h_{FE}	Max. C_{OB} (pf)	Min. f_T (mc)
2N2162	30	.01	2	20 at 1 kc	10	14
2N2163	15	.01	2	20 at 1 kc	10	14
2N2164	12	.02	1.5	25 at 1 kc	10	24
2N2165	30	.02	3	2.5 at 4 mc	10	10
2N2166	15	.02	3	2.5 at 4 mc	10	10
2N2167	12	.02	2.5	4 at 4 mc	10	16

For application engineering assistance without obligation, write Transistor Division, Product Marketing Section, Sprague Electric Co., Concord, N. H.

For complete technical data, write Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

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